

An Overview of the Impact of Energetic Particle Precipitation (EPP) on the Mesosphere and Stratosphere

Charles Jackman & Dean Pesnell

NASA Goddard Space Flight Center, Greenbelt, MD

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Cora Randall

University of Colorado, Boulder, CO

Howard Singer

NOAA Space Weather Prediction Center, Boulder, CO

Janet Kozyra

University of Michigan, Ann Arbor, MI

Manuel López-Puertas

Instituto de-Astrofísica de Andalucía, Granada, SPAIN

Eric Fleming

NASA Goddard Space Flight Center, Greenbelt, MD

Daniel Marsh, Francis Vitt, and Rolando Garcia

National Center for Atmospheric Research, Boulder, CO

Scott Bailey

Virginia Polytechnic Institute, Blacksburg, VA

Outline

I. What is EPP?

II. EPP-produced HO_x

III. EPP-produced NO_x

IV. Ozone impacts

V. Conclusions

Energetic Particle Precipitation

Electrons [and bremsstrahlung]



Auroral (~1-30 keV)

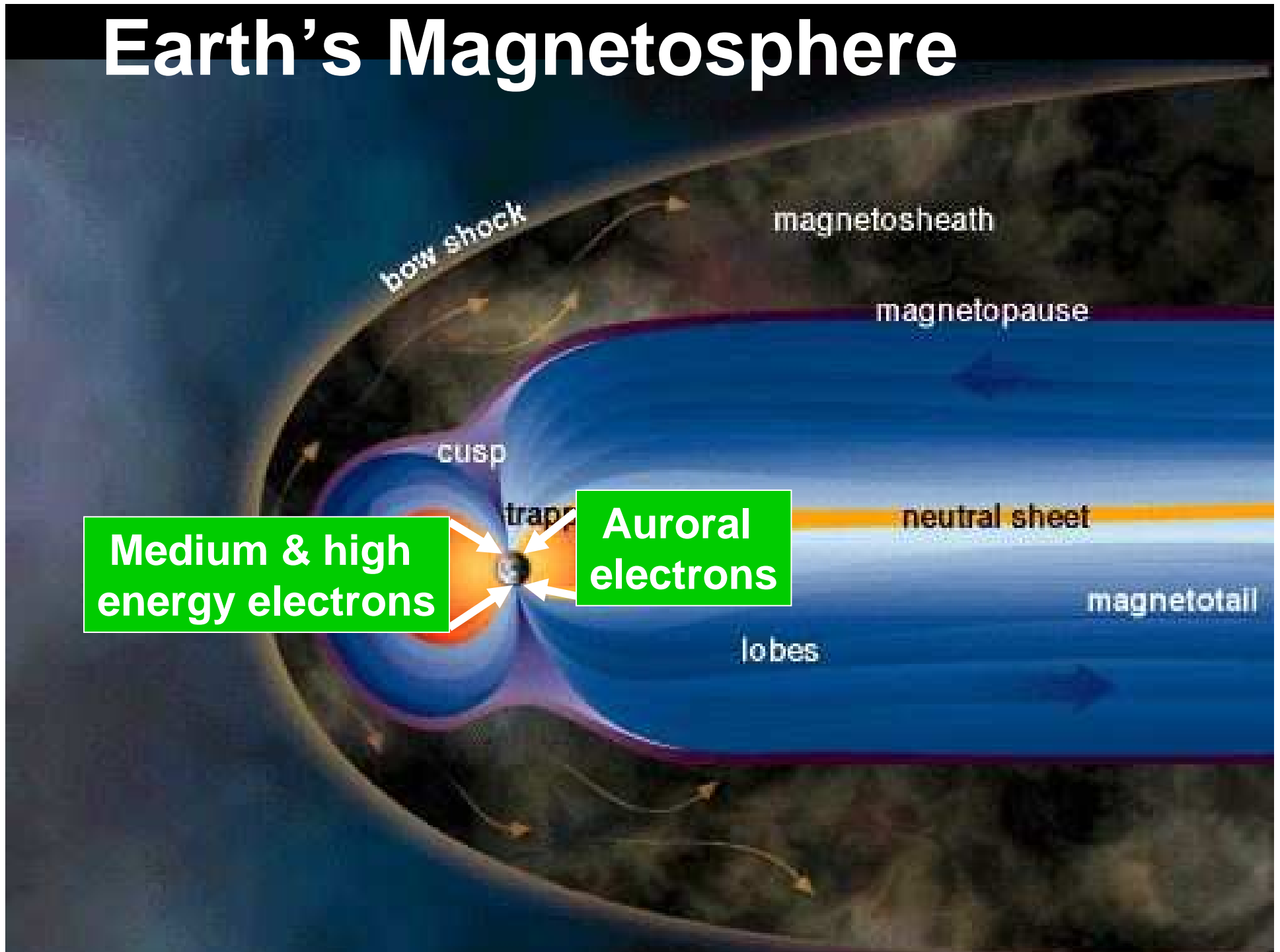
Medium energy (~30-300 keV)

High energy (~300-3000 keV)

Solar Protons

Medium to High energy (~1-300 MeV)

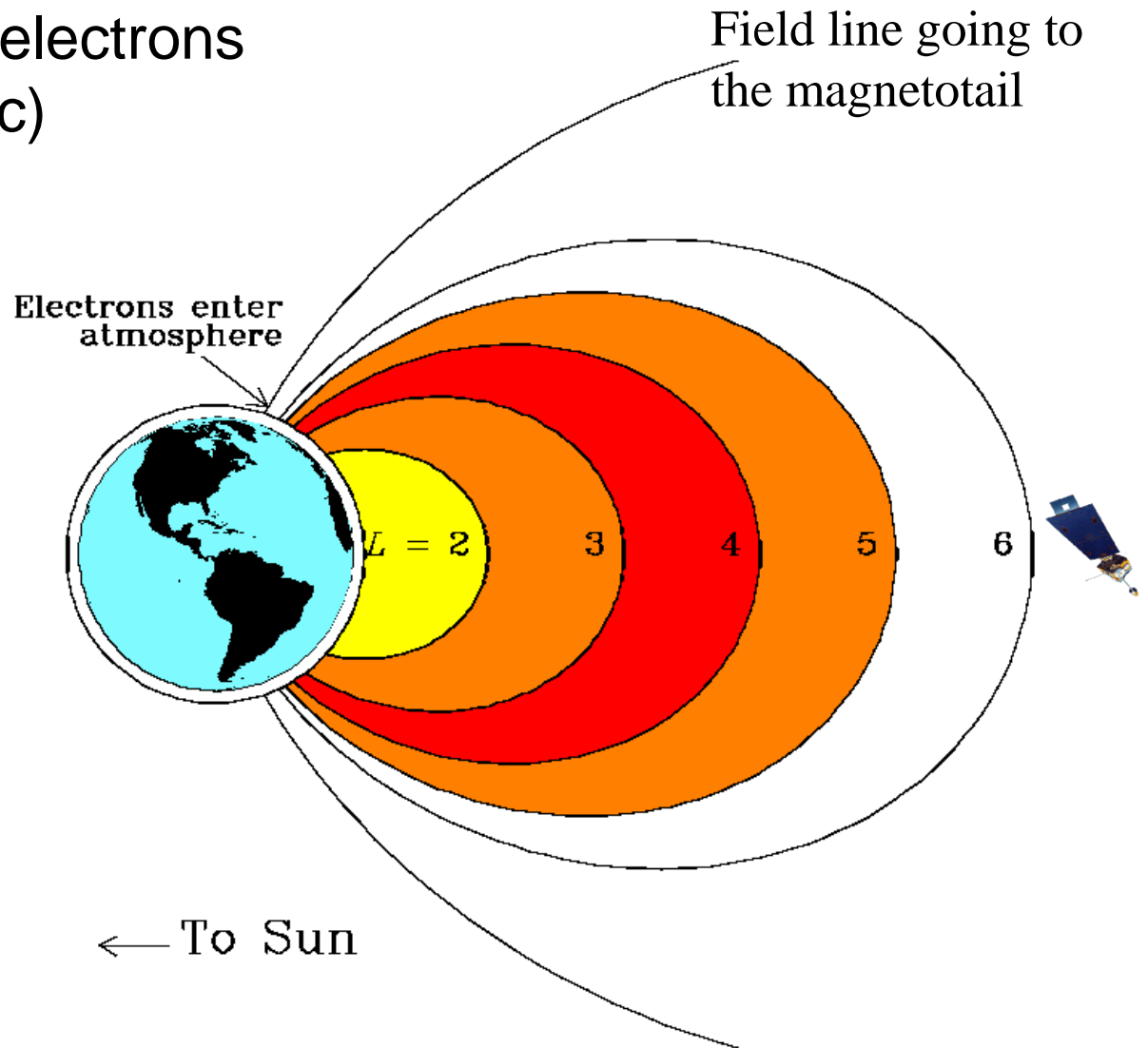
Earth's Magnetosphere



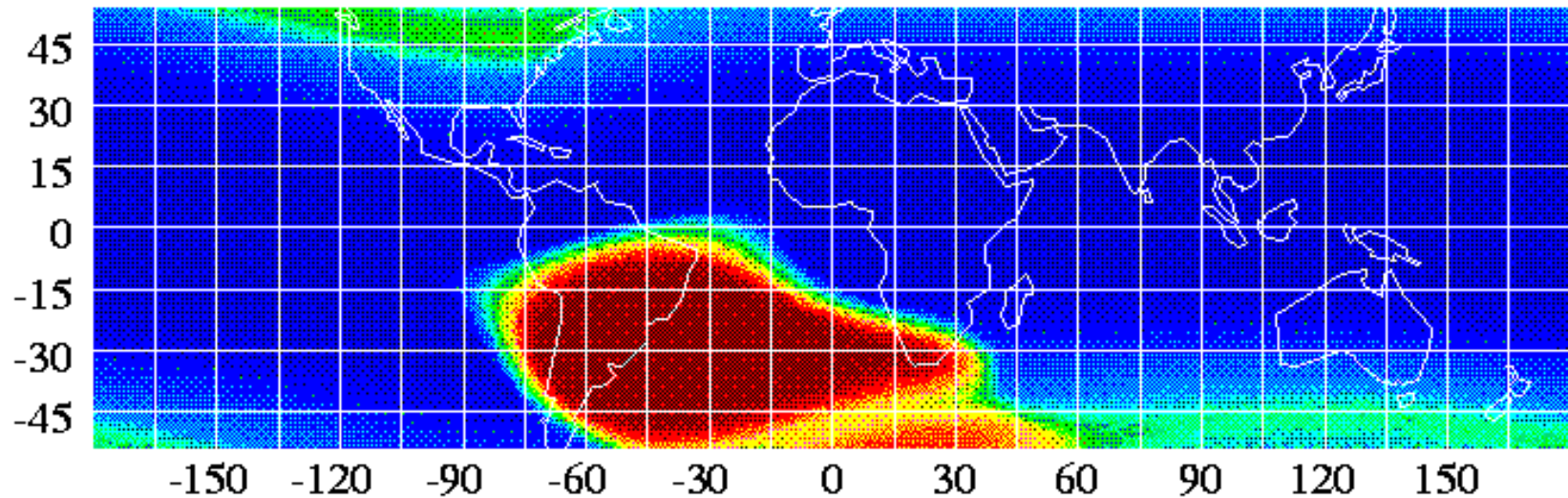
Energetic Electron Precipitation

Medium & high energy electrons
($E > 100$ keV, relativistic)
subauroral
diffuse
~55-65° geom. lat.

Spread in longitude
(not local time)
Accelerated in the
equatorial plane

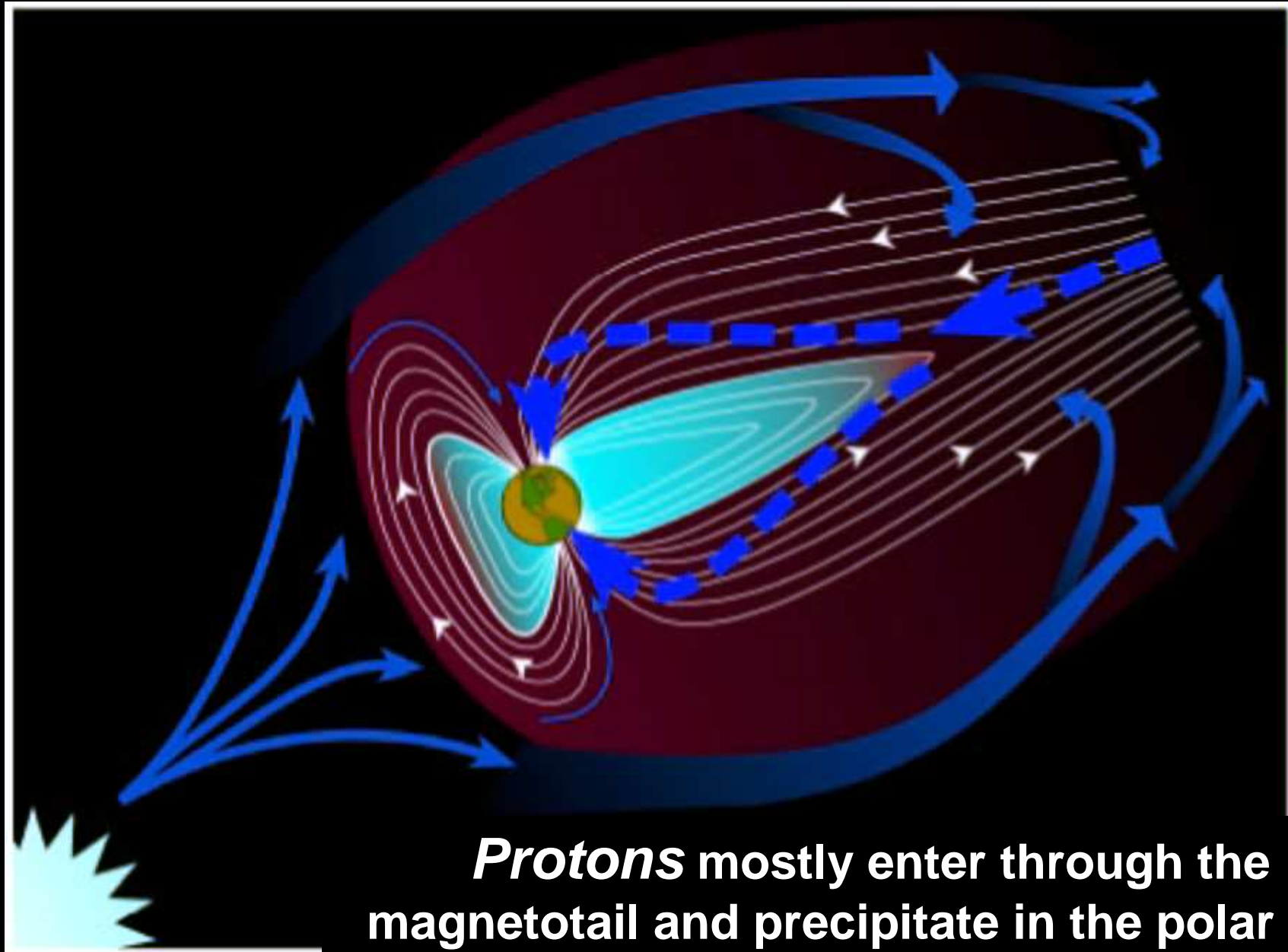


Electron Precipitation



The South Atlantic Anomaly – weak field – all electrons
→ low latitude [~ 0 - 30° S geom. lat., ~ 0 - 45° E geom. lon.]
This map shows the SAA in red using electron fluxes from ROSAT. The electron energies must be high enough to cause the extension under Africa and far south of the traditional area.

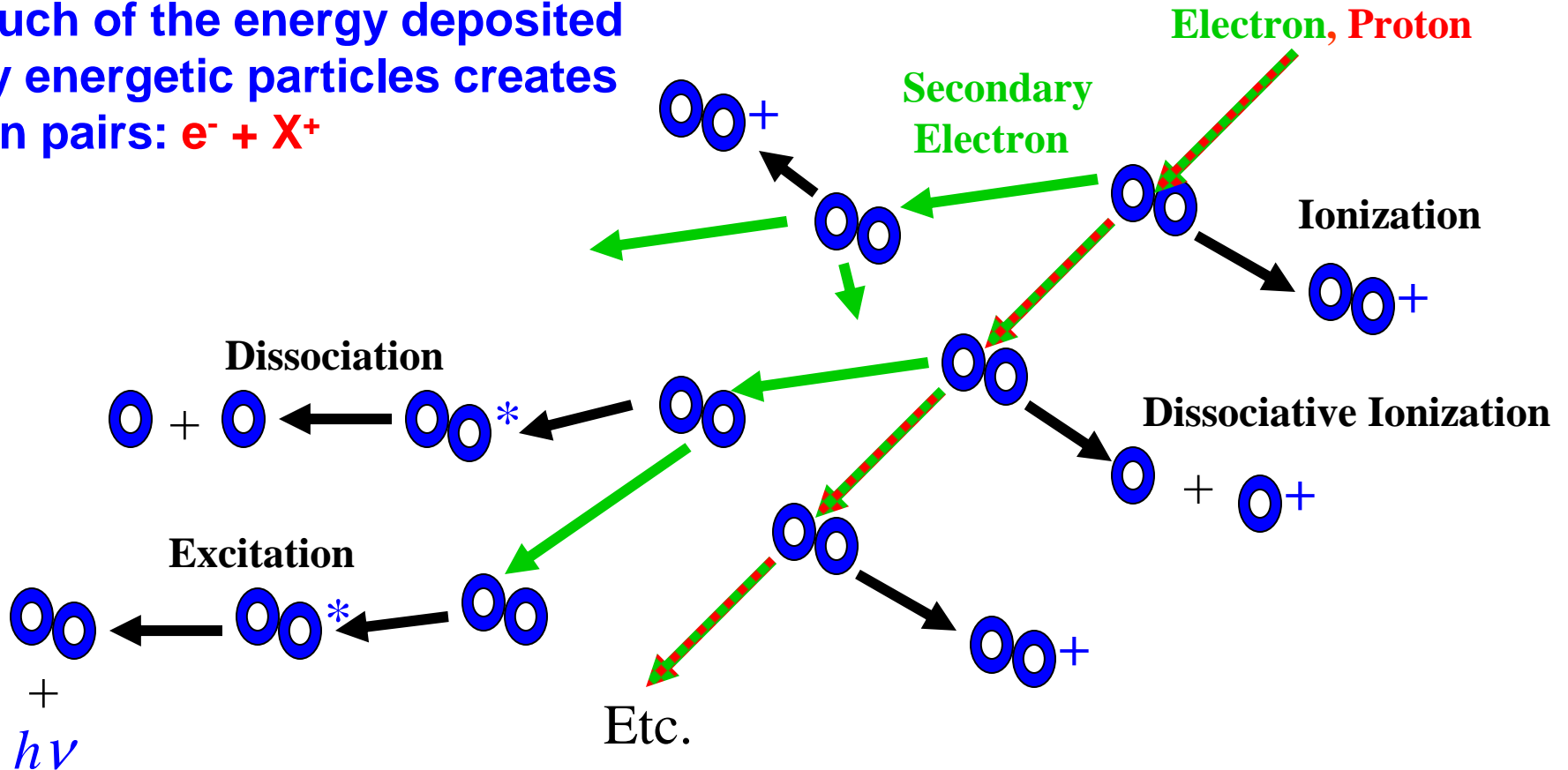
Solar Proton Events (SPEs)



Protons mostly enter through the magnetotail and precipitate in the polar cap

Electron or Proton Energy Deposition into Atmosphere

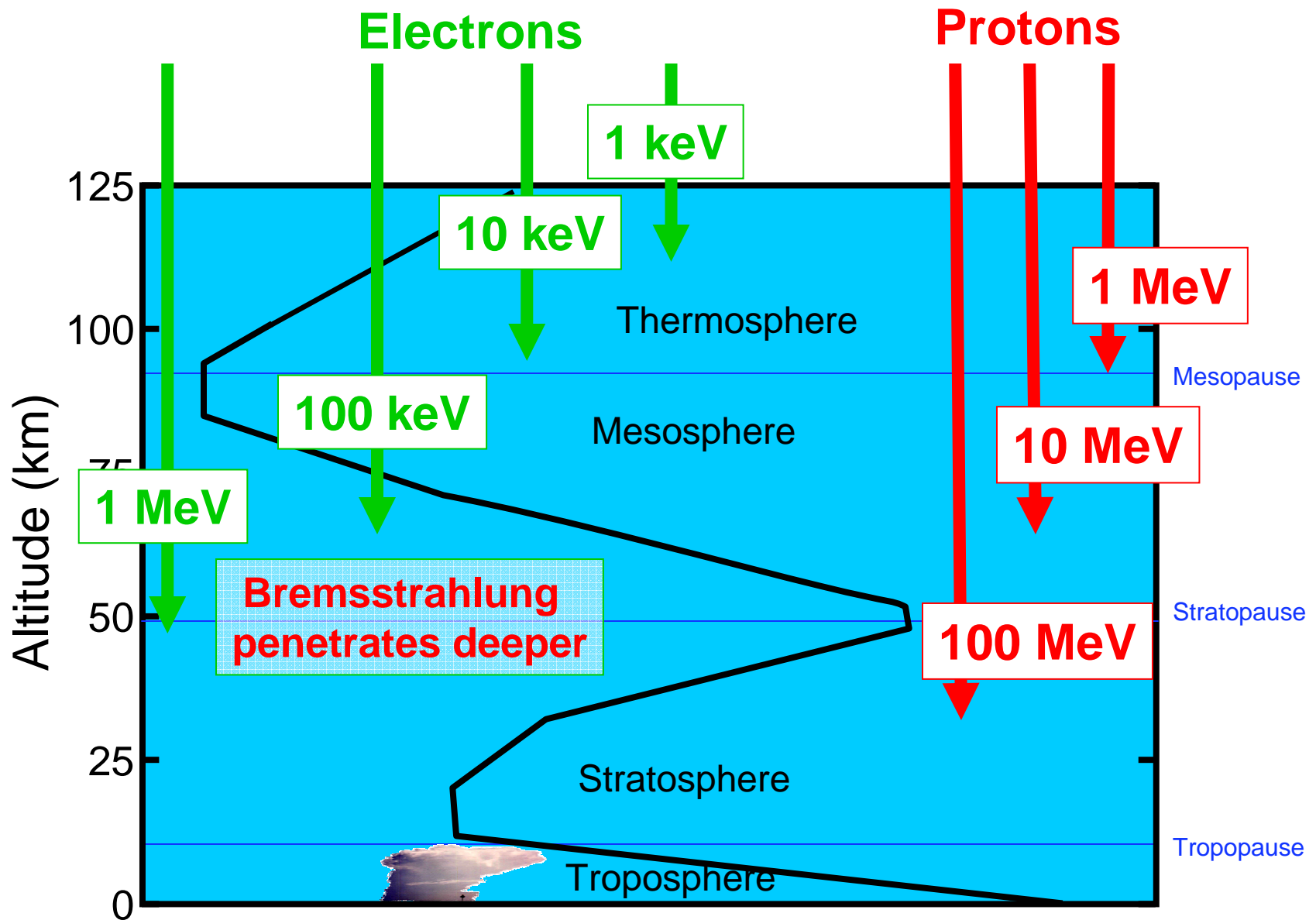
Much of the energy deposited by energetic particles creates ion pairs: $e^- + X^+$



and Emission

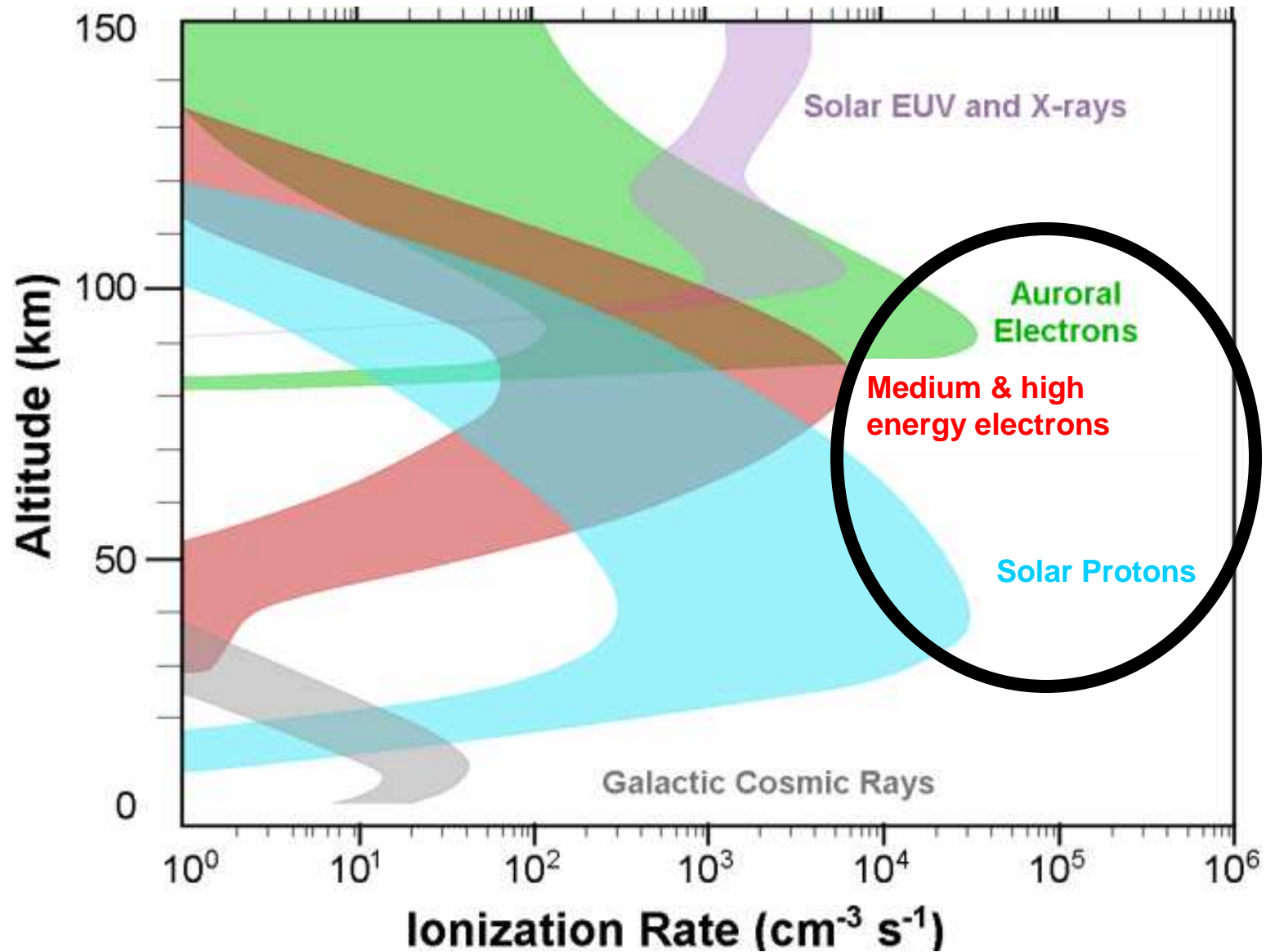
Relativistic electrons also produce bremsstrahlung X-rays

N_2^+ , N_2^* , N^+ , N , N^* , O_2^+ , O_2^* , O^+ , O , and O^* produced



Atmosphere acts as an energy filter

Energetic Particle Precipitation



Energetic Particles can Produce

HO_x and NO_x:

Both of which can destroy Ozone

**HO_x recombines quickly on the
nightside and, although it was
interesting to study, I'll skip to the
effects of NO_x, which can
accumulate in the polar winter
stratosphere**

III. EPP-produced NO_x

Energetic Particles Enhance NO_x (N, NO, NO_2)

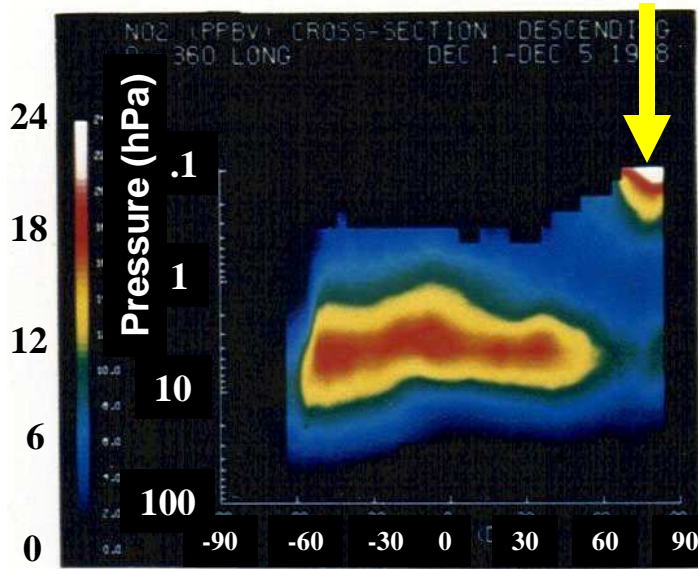
- NO_x constituents are produced by primary electrons and protons and associated secondary electrons dissociating N_2
 - Short- and long-term effects as NO_x constituents can last for weeks
- Production of 0.33 - 2.5 N atoms/ion pair estimated
- ~1.25 N atoms/ion pair is reasonable

Electrons Enhance NO_x (N, NO, NO_2)

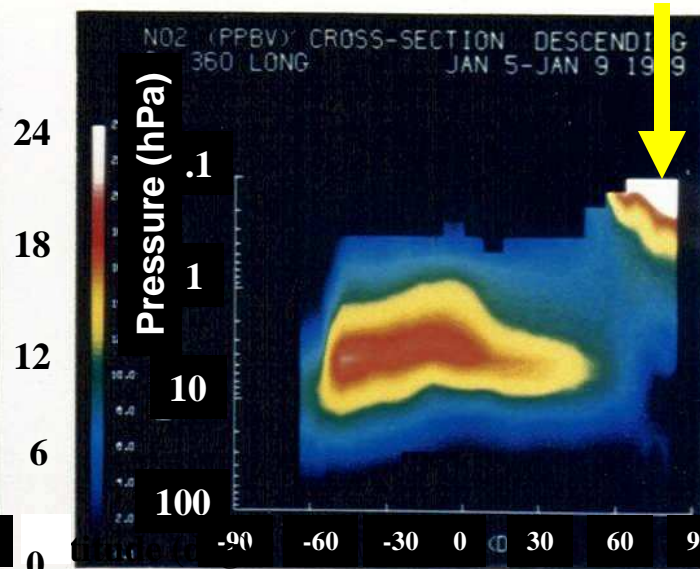
- **1960s** – Thermospheric NO production (electrons, EUV, X-rays) proposed & measured.

Electrons Enhance NO_x (N, NO, NO₂)

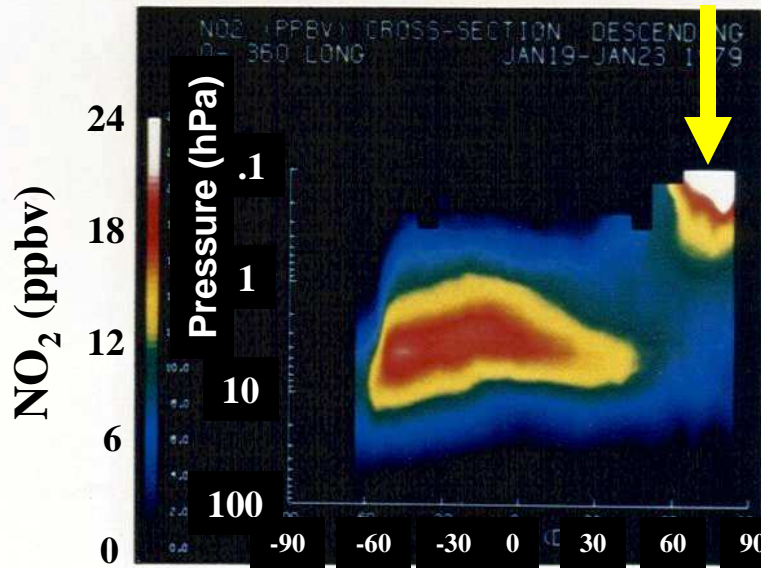
- **1960s** – Thermospheric NO production (electrons, EUV, X-rays) proposed & measured.
- **1970s** – Downward transport (especially in winter) of thermospheric NO production to middle atmosphere proposed. Relativistic electron precipitation (REP) impact first proposed.
- **1980s** – Further quantification (including observations) of downward transport of thermospheric NO production by electrons proposed. More REP work.



DECEMBER 1-5, 1978



JANUARY 5-9, 1979



JANUARY 19-23, 1979

LIMS NO₂ obs.

from Russell
et al. (1984)

Electrons Enhance NO_x (N, NO, NO_2)

- **1990s** – REP effects modeled in atmosphere.
Diffuse aurora & medium energy electron effects proposed.
Energetic electron precipitation (EEP) first used to define all electron impact.

Electrons Enhance NO_x (N, NO, NO_2)

- **1990s** – REP effects modeled in atmosphere.
Diffuse aurora & medium energy electron effects proposed.
Energetic electron precipitation (EEP) first used to define all electron impact.
- **2000s** – Observations (ACE, GOMOS, MIPAS, HALOE, POAM II/III, ILAS-II) show evidence of downward transport (especially in winter) of thermospheric NO production to middle atmosphere.

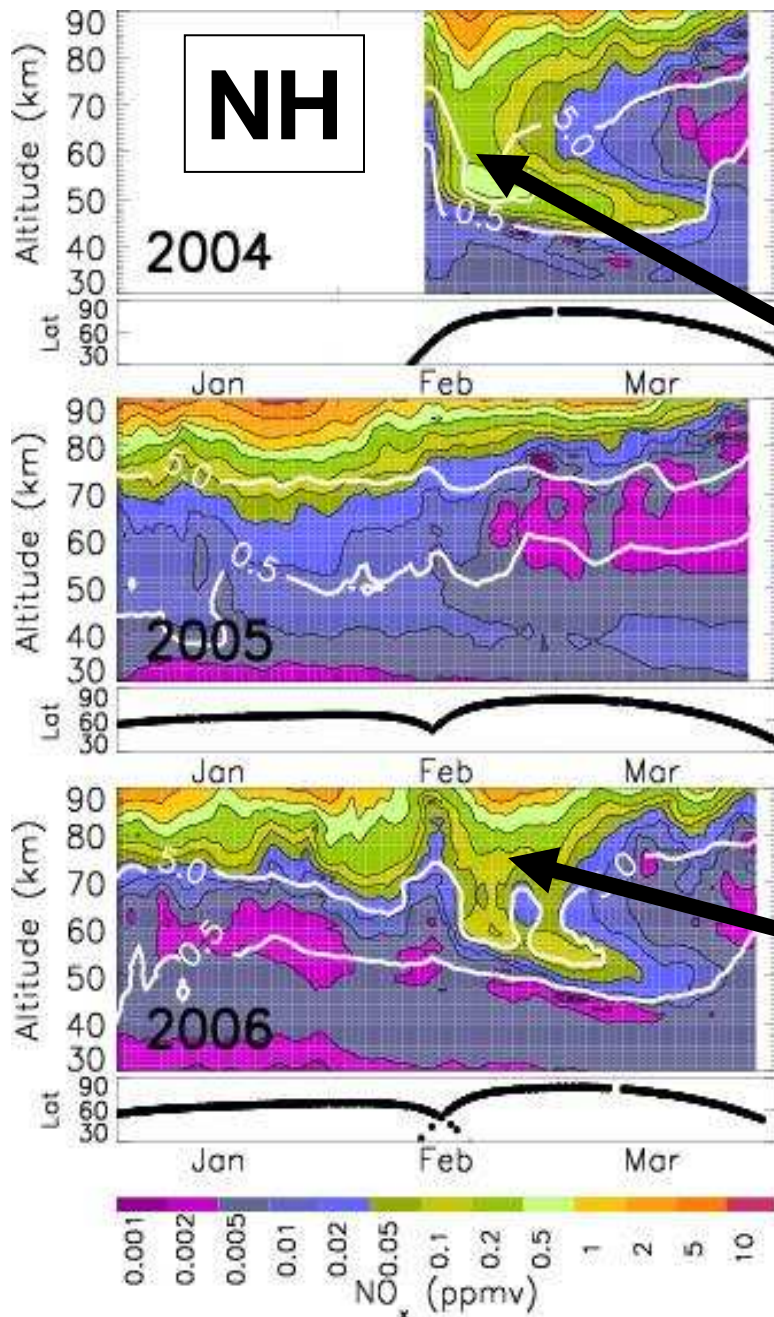
**More NO_x descends in NH in 2004 & 2006 than ever before observed
→ Use SciSat-1 ACE (50-85°N)**

2003-2004:

- Halloween Storms
- Unusual Meteorology
 - Unprecedented vortex in Feb-Mar
 - Elevated stratopause in Jan-Feb

2005-2006:

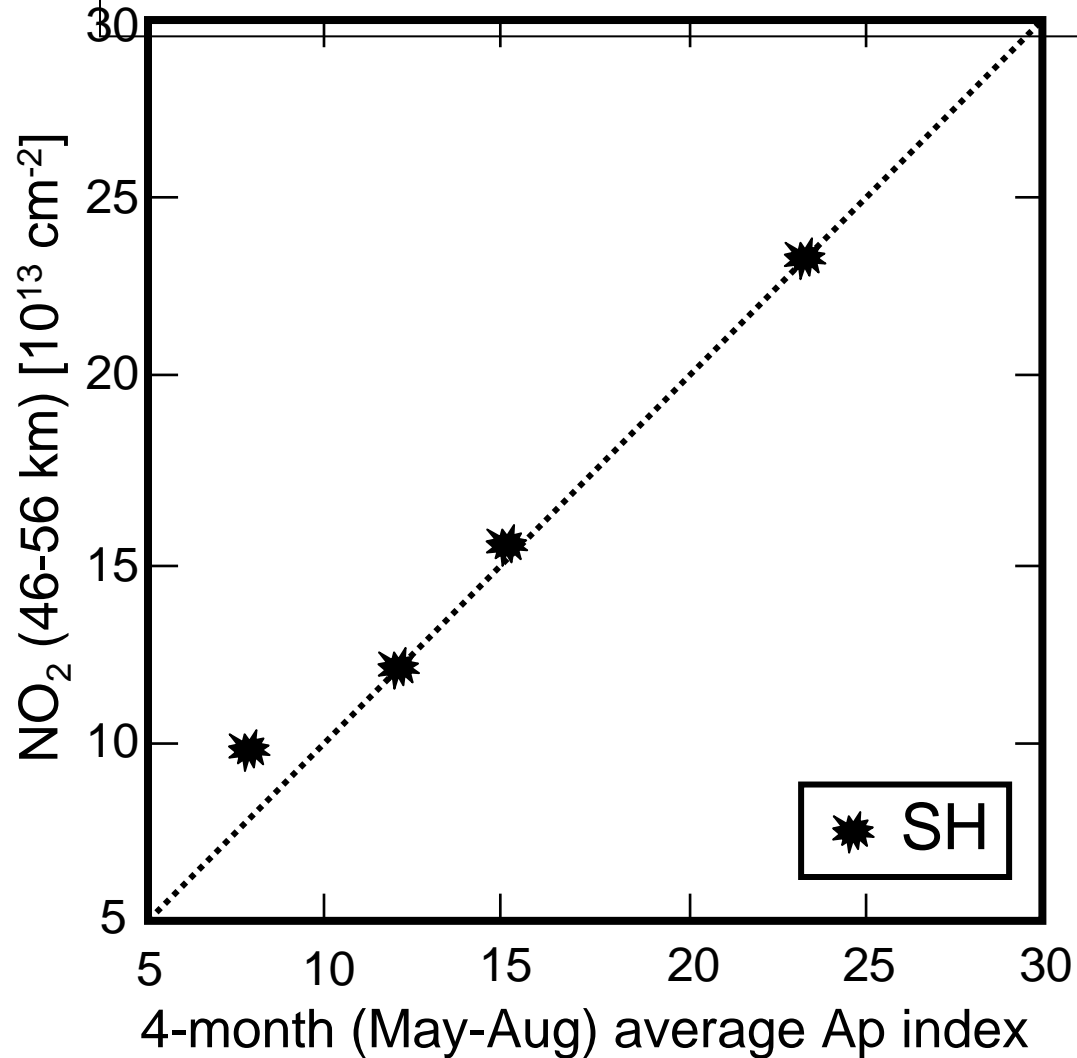
- **Not much EPP**
- Unusual Meteorology
 - Unprecedented vortex in Feb-Mar
 - Elevated stratopause in Jan-Feb



From Randall et al. (2006)

Near linear relationship between SH NO₂ (upper stratosphere/lower mesosphere) & Ap index

→ Use GOMOS for 2003-2006



Adapted from
Seppälä et al. (2007)

Solar Protons Enhance NO_x (N, NO, NO_2)

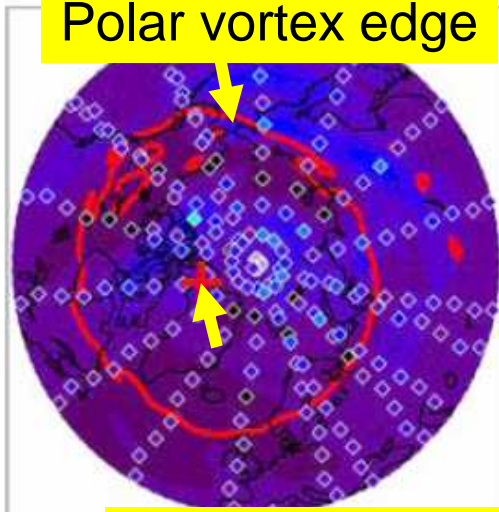
- **1970s** – Mesospheric & stratospheric NO_x production proposed from solar protons.

Solar Protons Enhance NO_x (N, NO, NO₂)

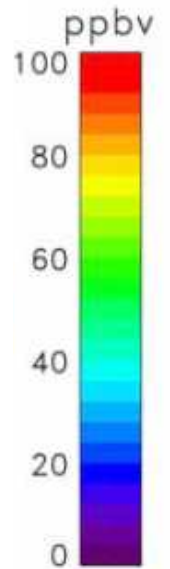
- **1970s** – Mesospheric & stratospheric NO_x production proposed from solar protons.
- **1980s & 1990s** – Mesospheric & stratospheric NO_x production observed & modeled from solar protons.
- **2000s** – Mesospheric & stratospheric NO_x (NO, NO₂) and other NO_y (HNO₃, N₂O₅, ClONO₂) constituents observed (MIPAS, HALOE, GOMOS) & modeled from solar protons.

27-Oct-2003

Polar vortex edge

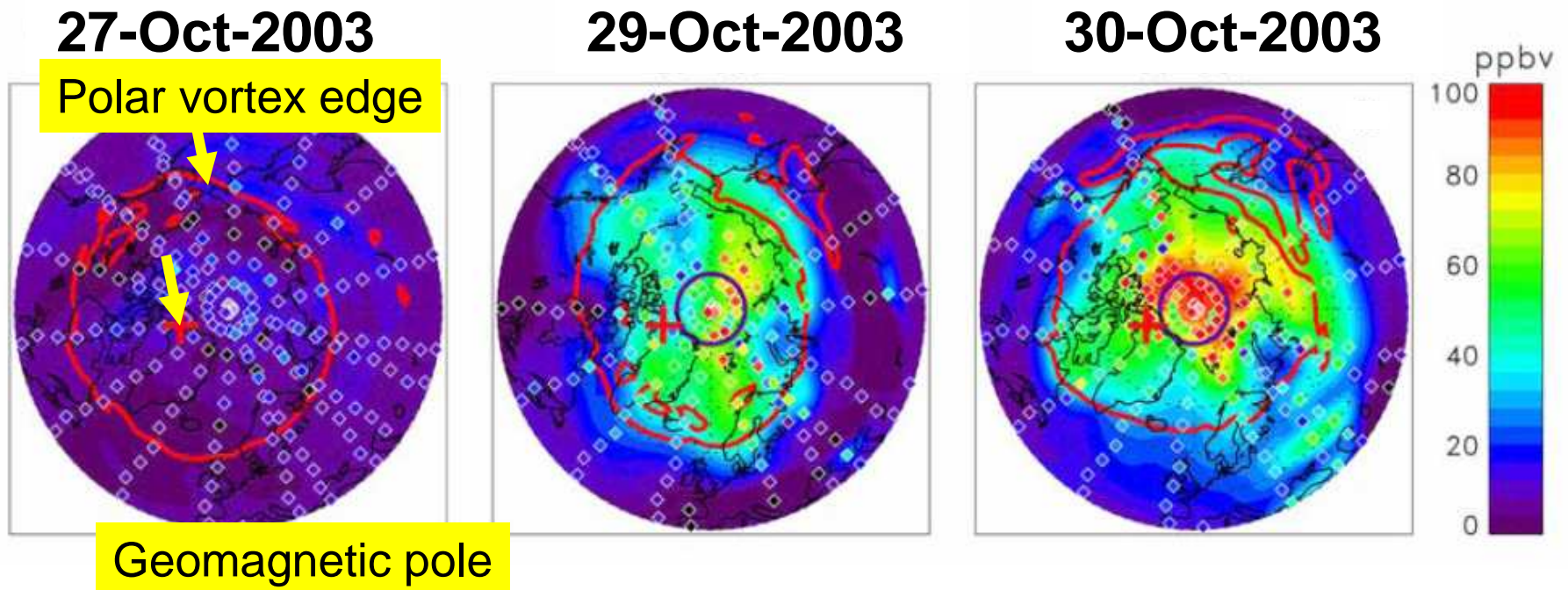


Geomagnetic pole



**MIPAS NO_x (NO+NO₂) in 50-55 km
(Northern Hemisphere)**

Lopez-Puertas et al. [2005a]

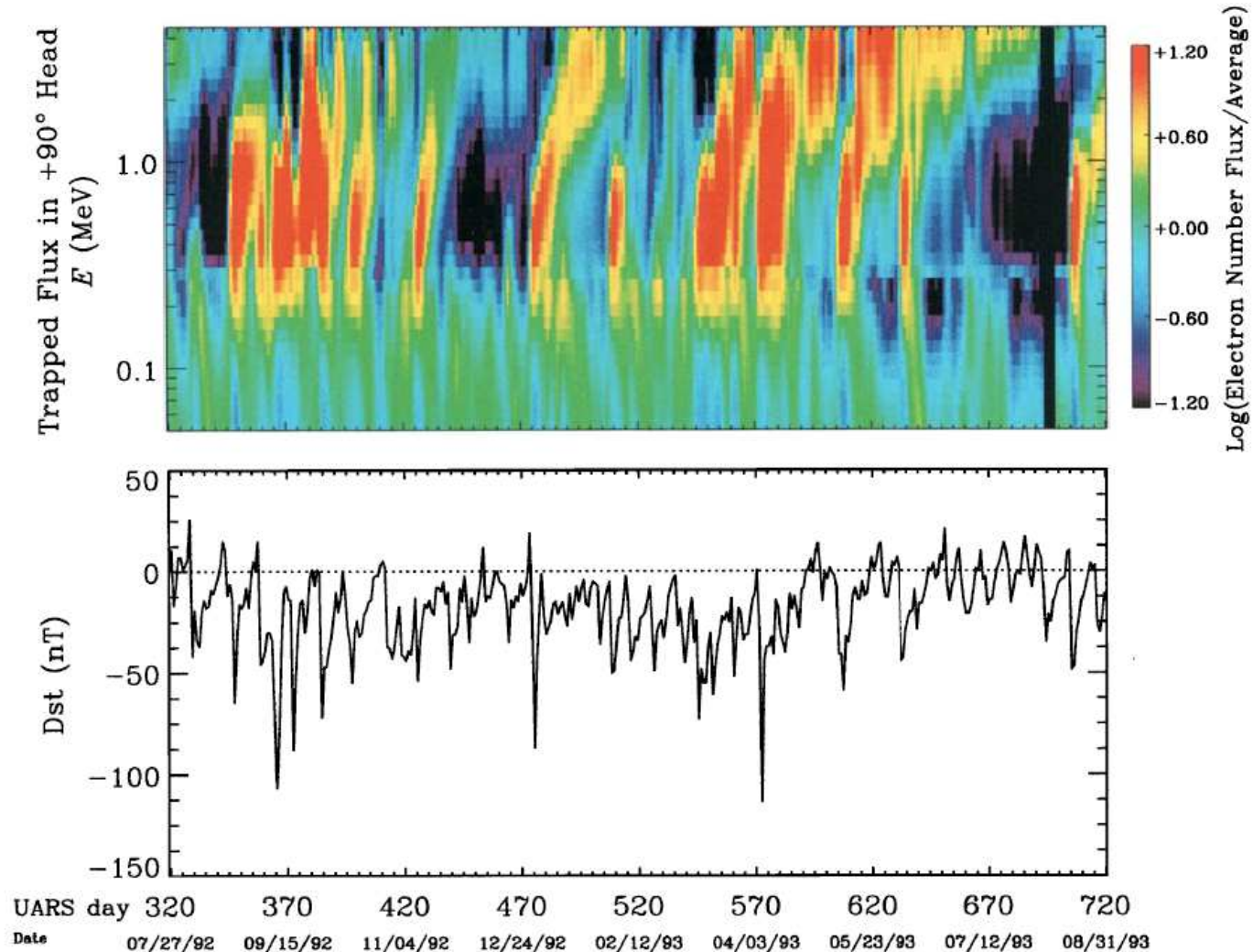


MIPAS NO_x (NO+NO₂) in 50-55 km (Northern Hemisphere)

Enhanced by Oct. 2003 Solar Proton Event

Lopez-Puertas et al. [2005a]

Relative Electron Spectrum, $L \sim 3$



Thank You, Questions?