# Observations of Three Dimensional Neutral Composition Changes in the Thermosphere During Geomagnetic Storms.


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# Overview

- Instrumentation
- Methodology
- May 2003 event
- Discussion

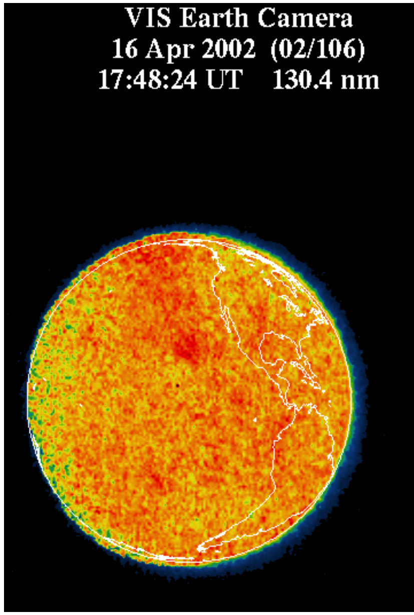
# Instrumentation

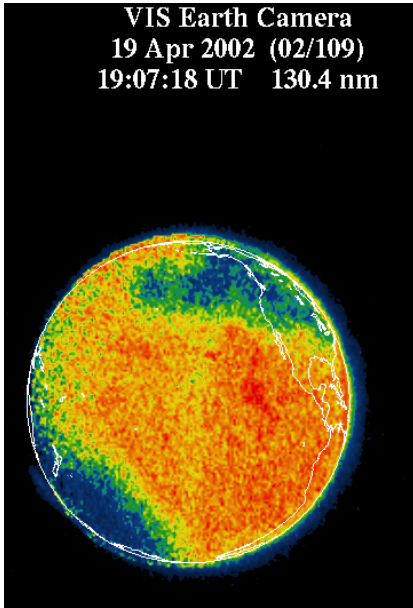
- Visible Imaging System (VIS) on the Polar Spacecraft
  - VIS Earth Camera sensitive at far-ultraviolet (FUV) wavelengths 124-149 nm predominantly OI 130.4 and 135.6 nm with a smaller contribution from $N_2$ LBH 138-149 nm, 20° × 20°
  - Image cadence 54 s.
- Global Ultraviolet Imager (GUVI) on the TIMED spacecraft
  - GUVI is an FUV scanning imaging spectrograph that provides horizon-to-horizon images and limb scans in five selectable wavelength intervals covering HI 121.6 nm, OI 130.4 nm, OI 135.6 nm, and $N_2$ Lyman-Birge-Hopfield bands 140 to 150 nm and 165 to 180 nm.

# Motivation

## $O/N_2$ Composition Observations

- An important indicator for the condition of the upper atmosphere is the relative abundance of O and $N_2$ in the thermosphere.
- These are the major constituents of the thermosphere and play dominant roles in the atmospheric chemistry.
- The relative abundance of the $O/N_2$ can be determined using FUV wavelengths.

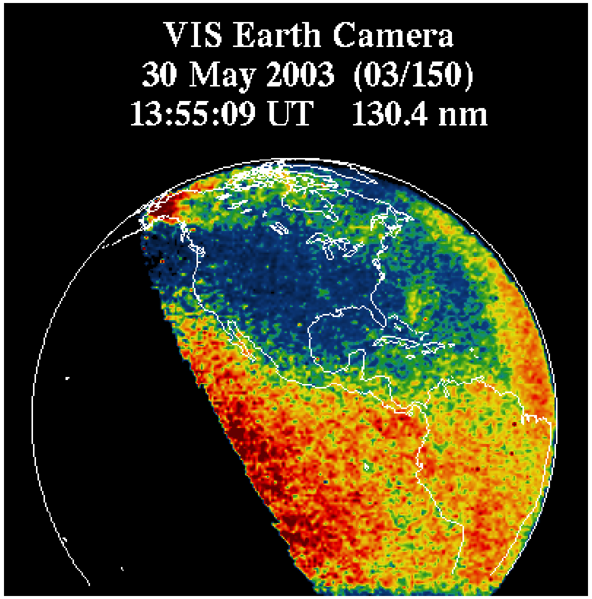


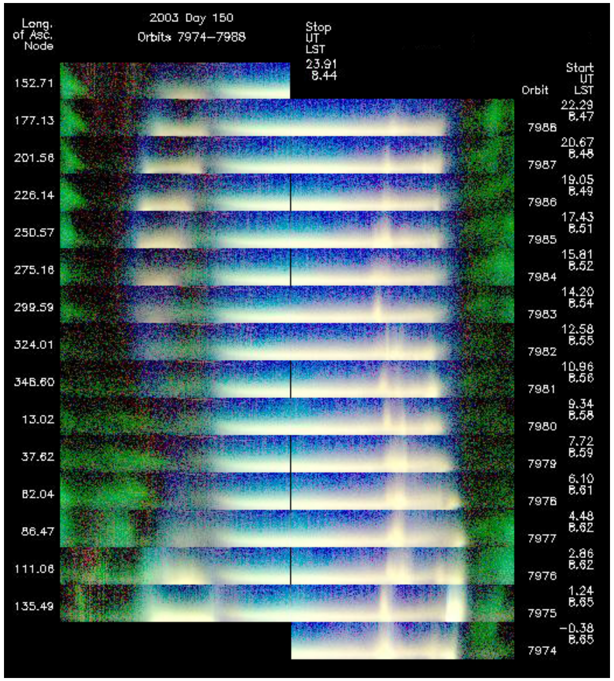
The $O/N_2$ neutral density ratio can be used to infer the daytime ionospheric density. Where solar illumination is the dominant ionization source and charge exchange followed by molecular ion recombination is the dominant ionization loss path, the ionospheric density is proportional to the $O/N_2$ ratio.

$$n_e \propto \frac{[O]}{[N_2]}$$

# Methodology




- Global images of the $O/N_2$ column density ratio have been obtained from broadband FUV observations of the dayglow with the Polar/VIS Earth Camera. Because the VIS Earth camera sensitivity as a function of wavelength was designed to match that of the Dynamics Explorer 1 ultraviolet imaging photometer, the method of Strickland et al. [1999, 2001] can be applied directly to the VIS images.



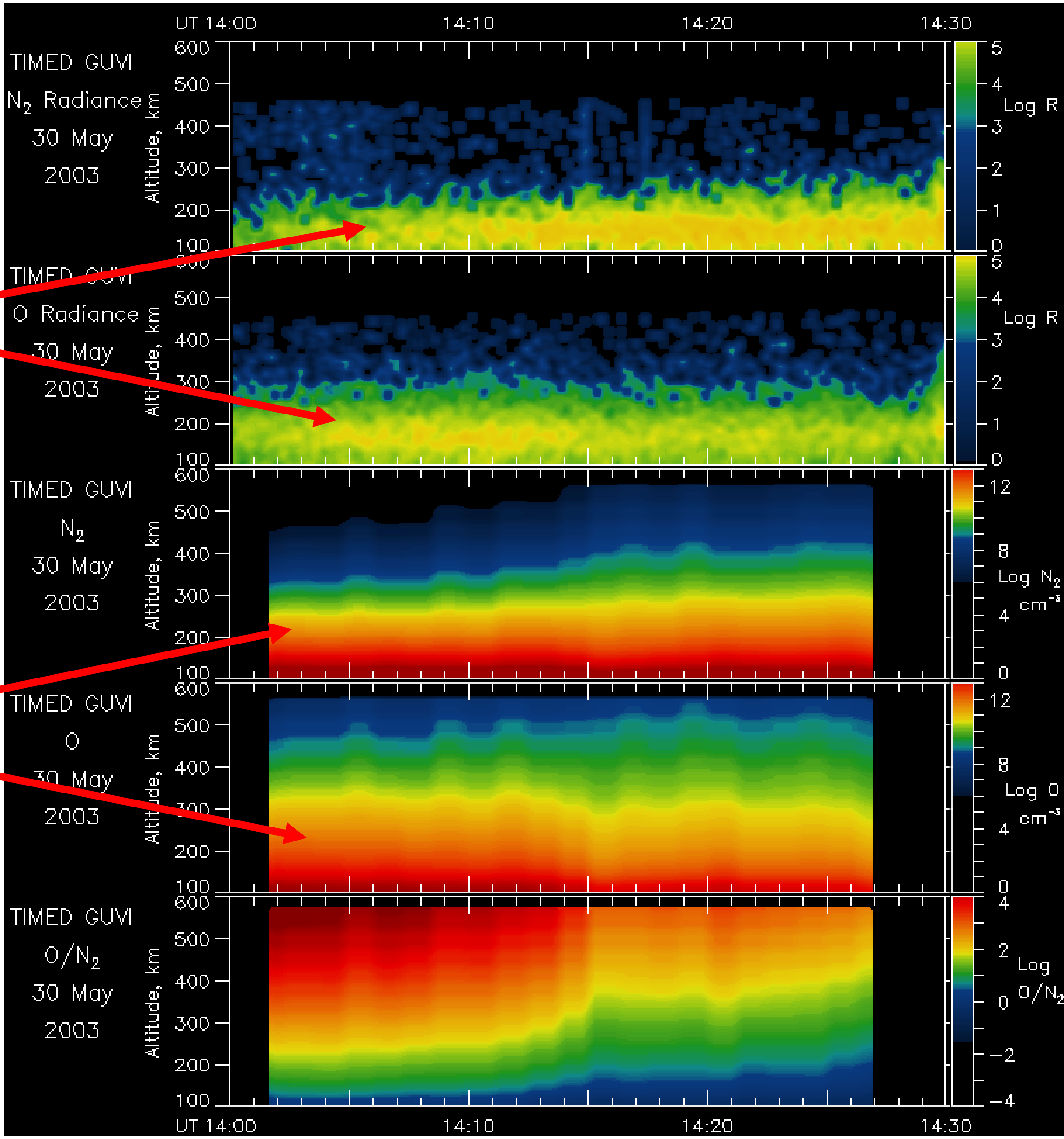

- Limb scans of the dayside thermosphere FUV emissions from TIMED/GUVI are inverted by discrete inverse transform to provide profiles of O and $N_2$ densities with *altitude*. [Meier et al., 2005]

- The combination of the two sets of images provides a 3-dimensional picture of the dayside thermosphere.

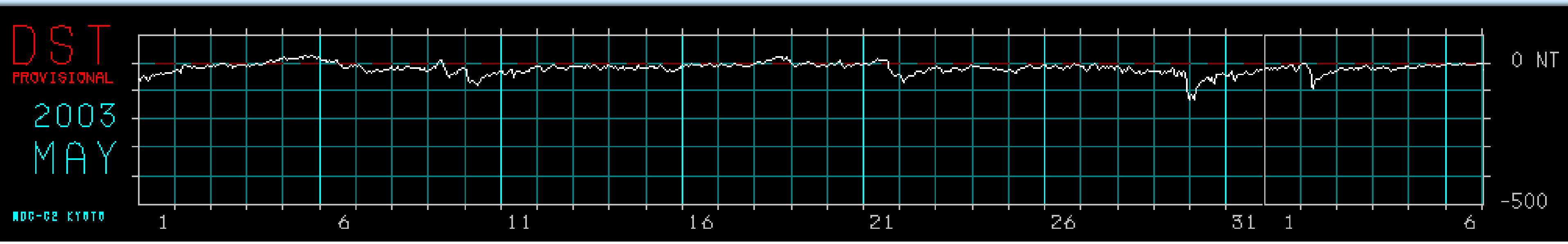
# Methodology

POLAR

TIMED/GUVI limb scans observations of thermospheric radiance are inverted to derive the altitude density profiles for $N_2$ and O and the $O/N_2$ density ratios at each altitude.

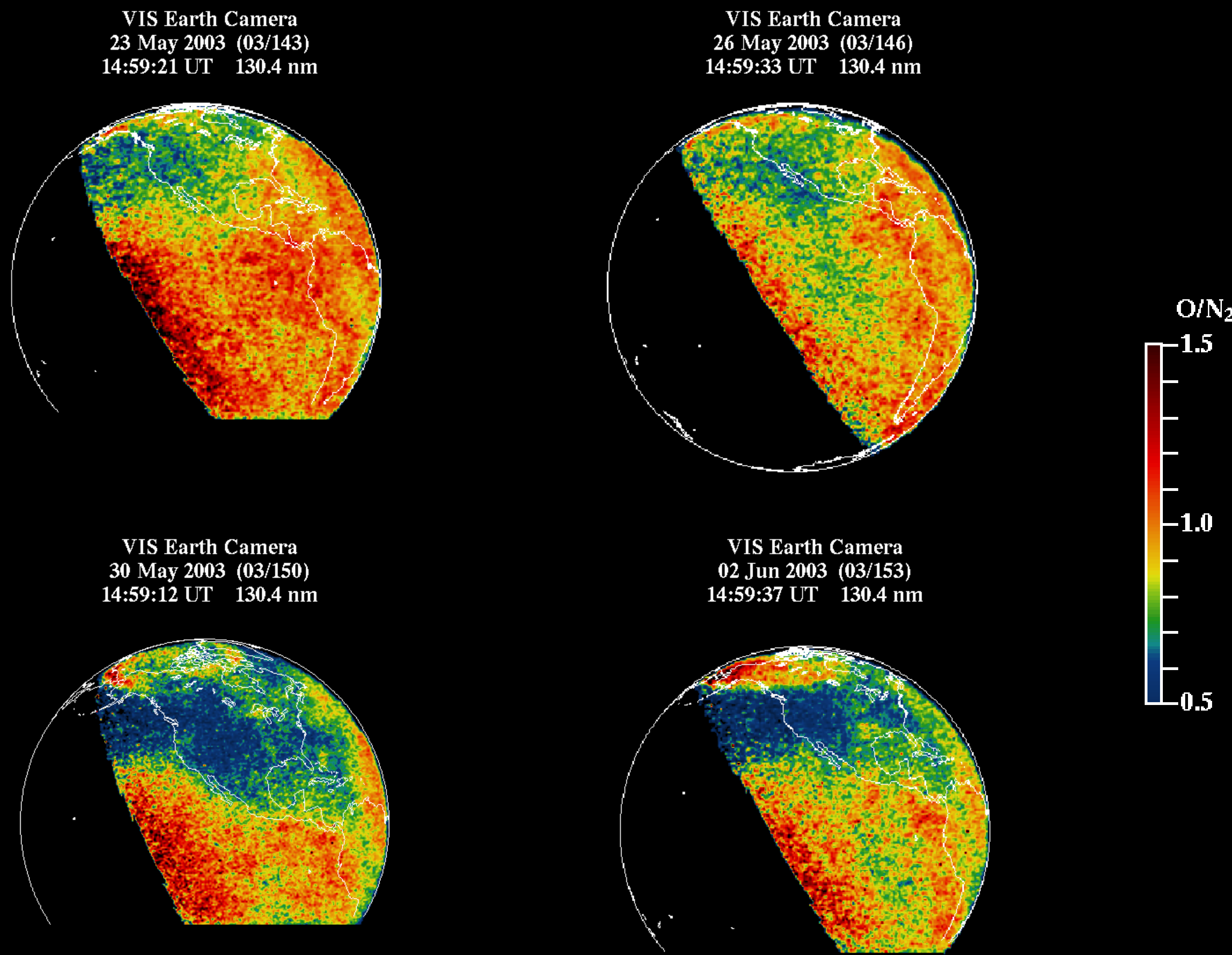


# $D_{st}$ for May 2003




| | |
|---|---|
| May 29, 2003 22 UT | Storm begins |
| May 30, 2003 3 UT | -131 nT |

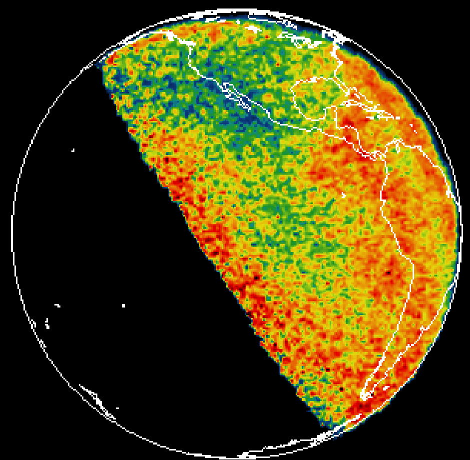
Provisional $D_{st}$ are provided by the World Data Center for Geomagnetism, Kyoto.


VIS Earth Camera
23 May 2003 (03/143)
14:59:21 UT 130.4 nm
VIS Earth Camera
26 May 2003 (03/146)
14:59:33 UT 130.4 nm
VIS Earth Camera
30 May 2003 (03/150)
14:59:12 UT 130.4 nm
VIS Earth Camera
02 Jun 2003 (03/153)
14:59:37 UT 130.4 nm
O/N2
1.5
1.0
0.5

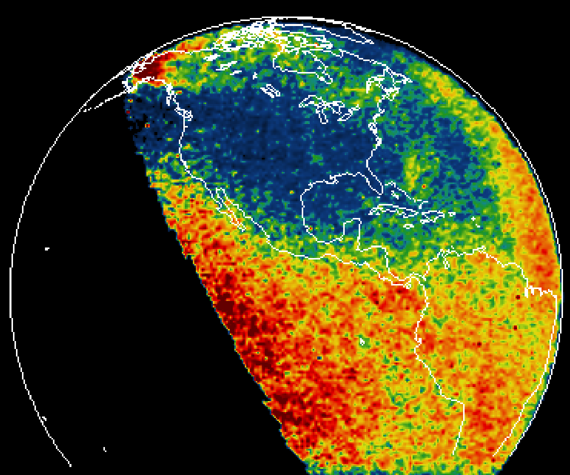
POLAR

TIMED

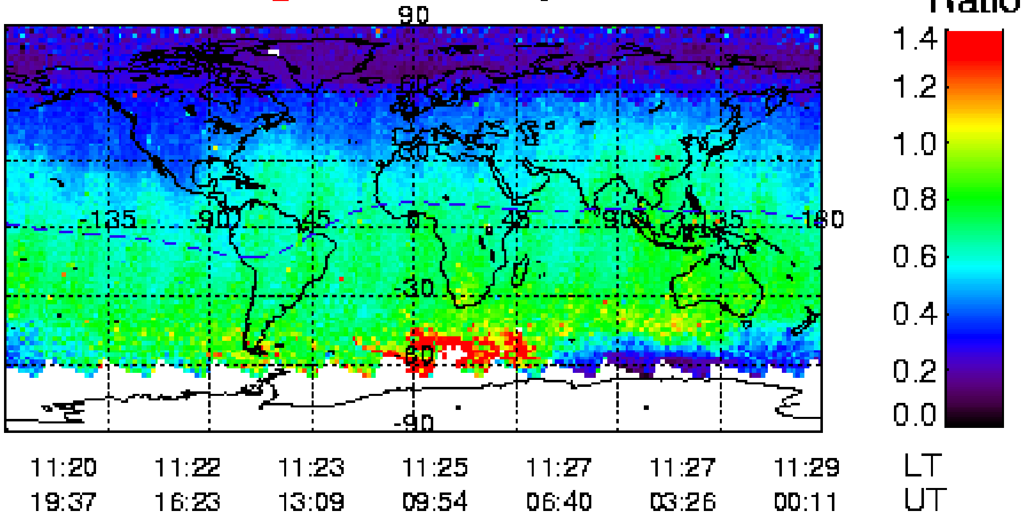
VIS Earth Camera
26 May 2003 (03/146)
14:59:33 UT 130.4 nm



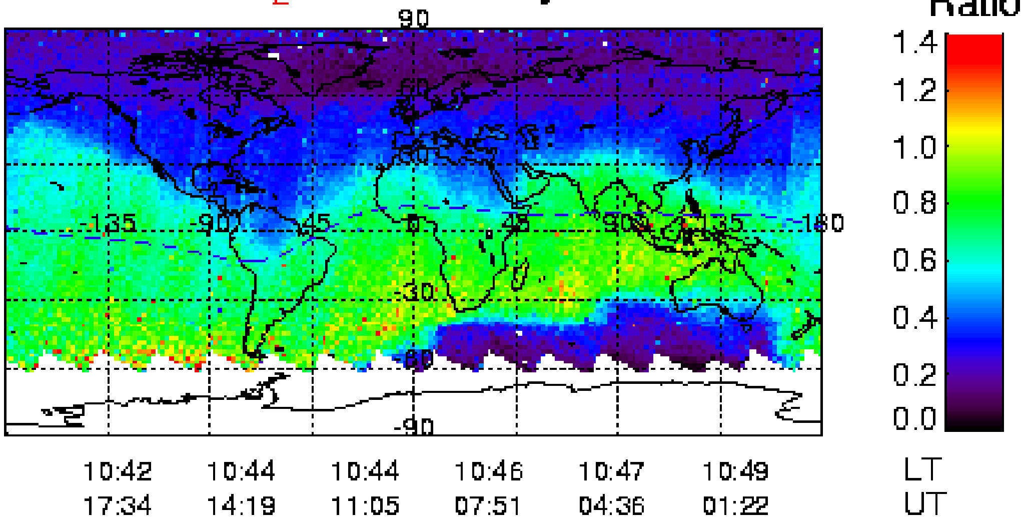
VIS Earth Camera
30 May 2003 (03/150)
13:55:09 UT 130.4 nm



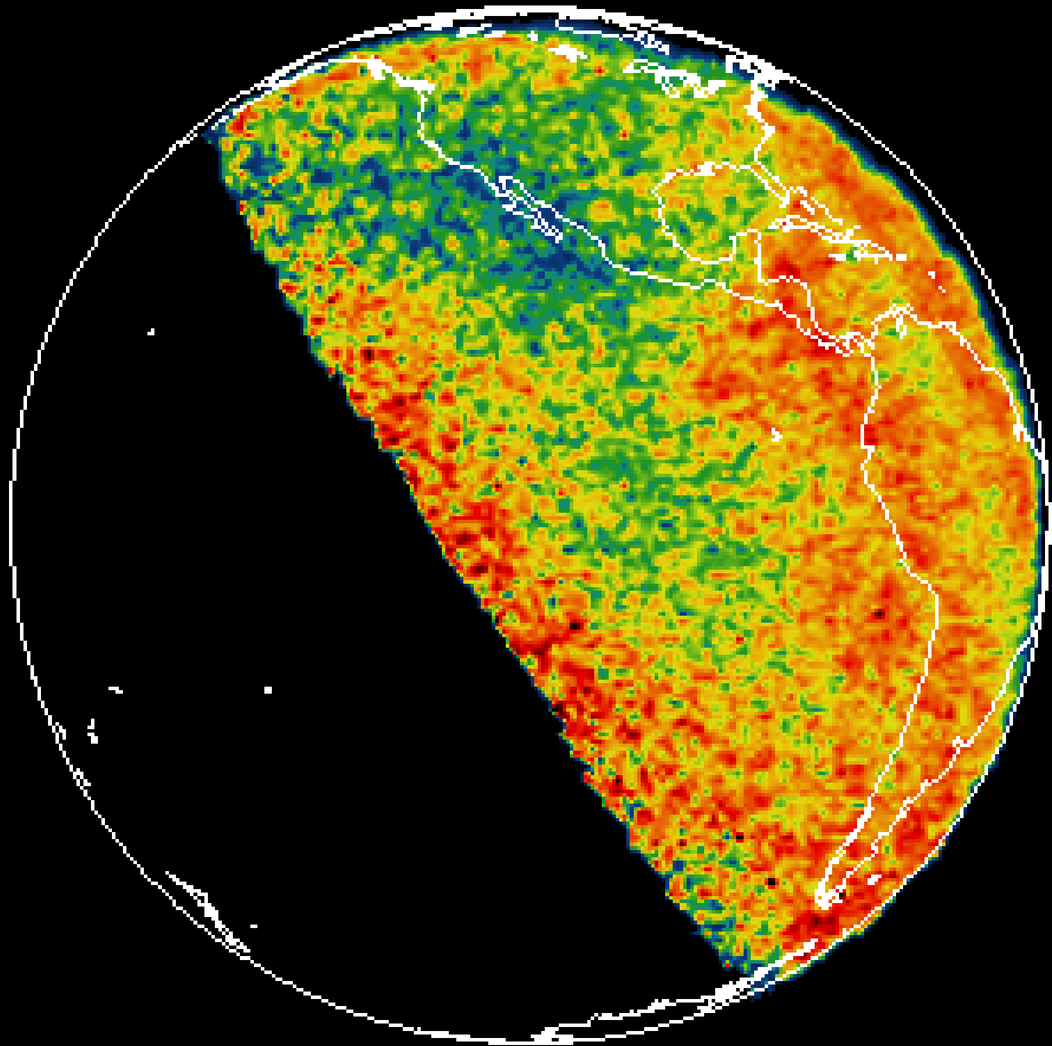
GUVI O/$N_2$ Ratio May 26, 2003

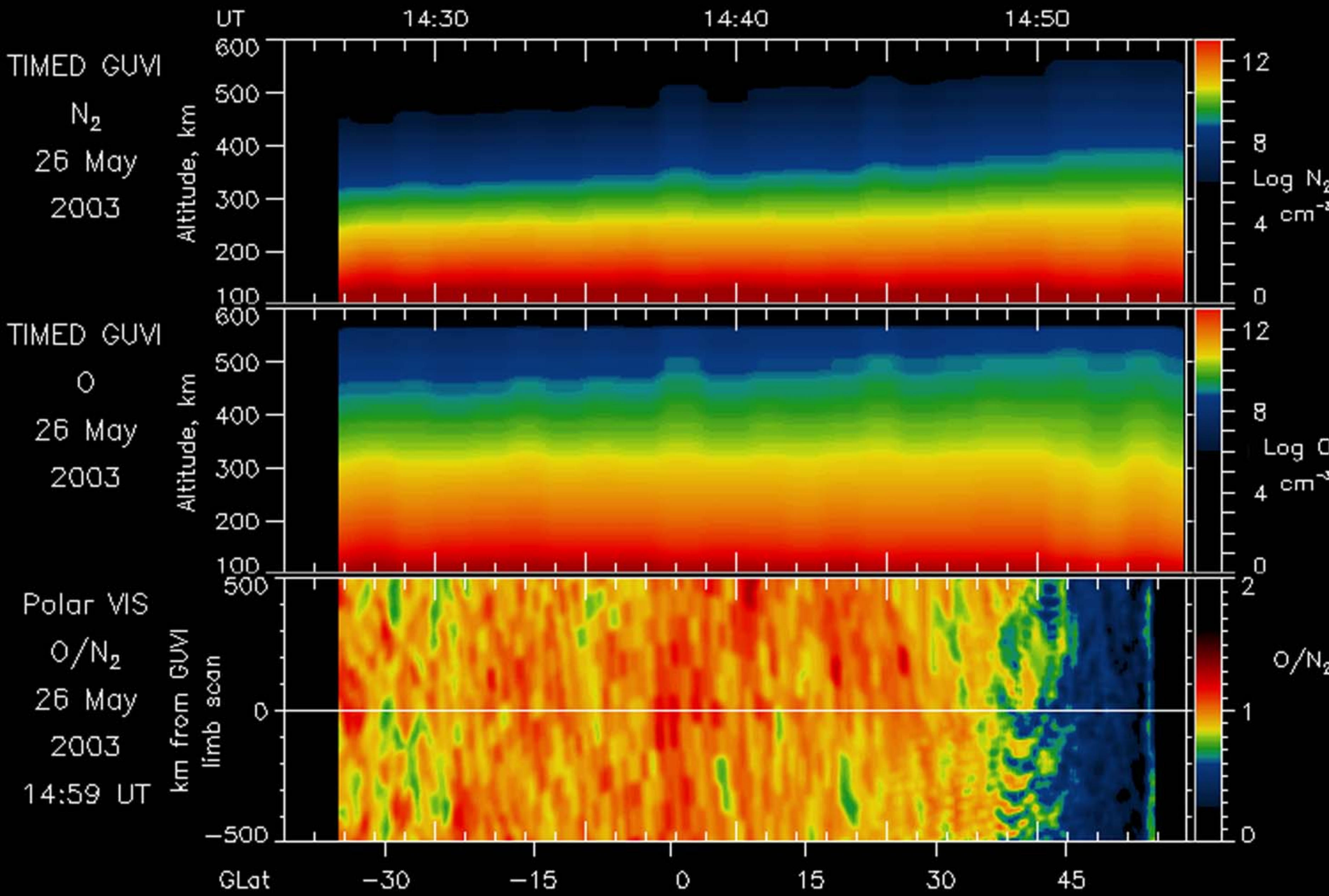



GUVI O/$N_2$ Ratio May 30, 2003

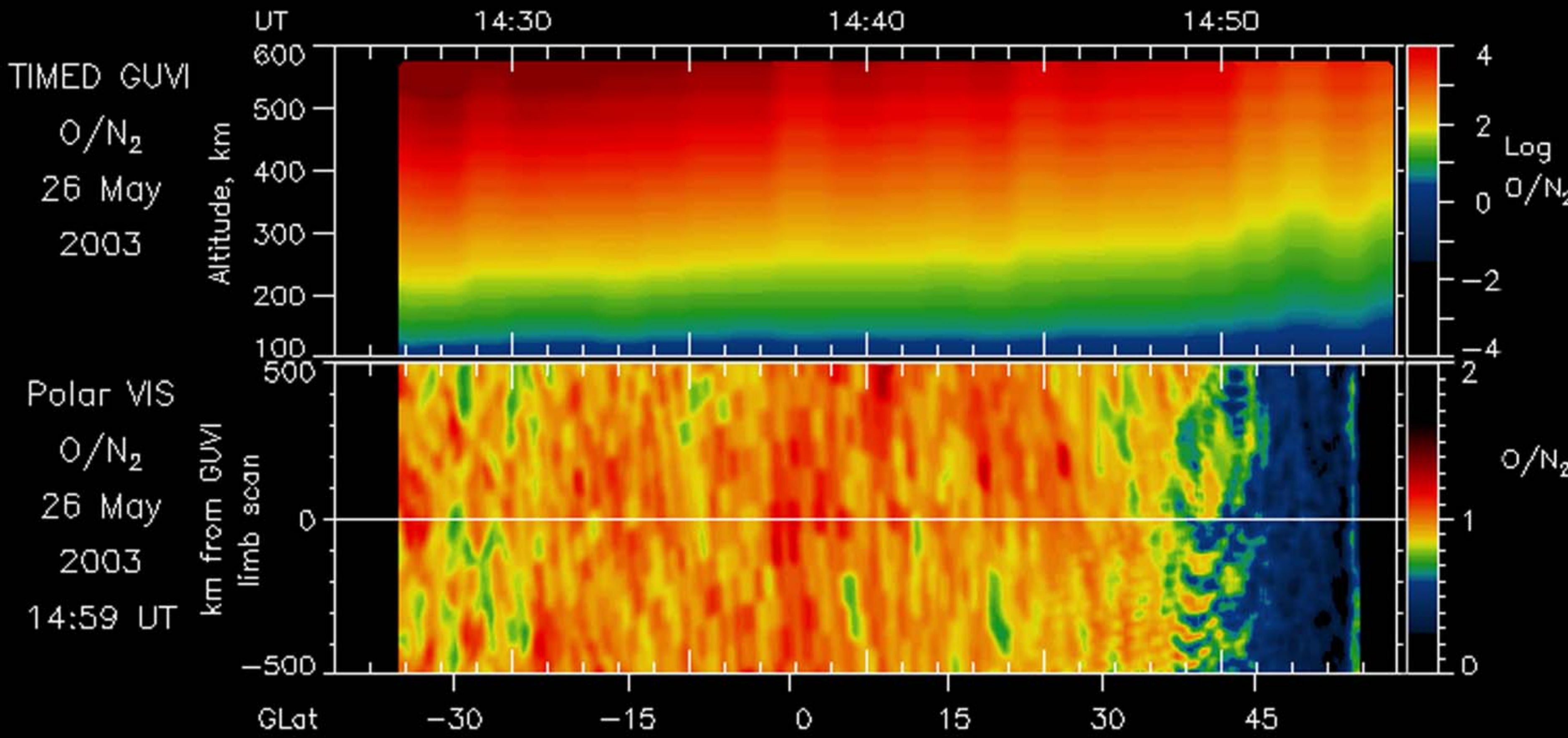


# VIS Earth Camera
26 May 2003 (03/146)
14:59:33 UT 130.4 nm





TIMED GUVI
$N_2$
26 May
2003
TIMED GUVI
O
26 May
2003
Polar VIS
$O/N_2$
26 May
2003
14:59 UT
UT
14:30
14:40
14:50
Altitude, km
600
500
400
300
200
100
Log $N_2$ $cm^{-3}$
Log O $cm^{-3}$
12
8
4
0
km from GUVI limb scan
500
0
−500
$O/N_2$
2
1
0
GLat
−30
−15
0
15
30
45

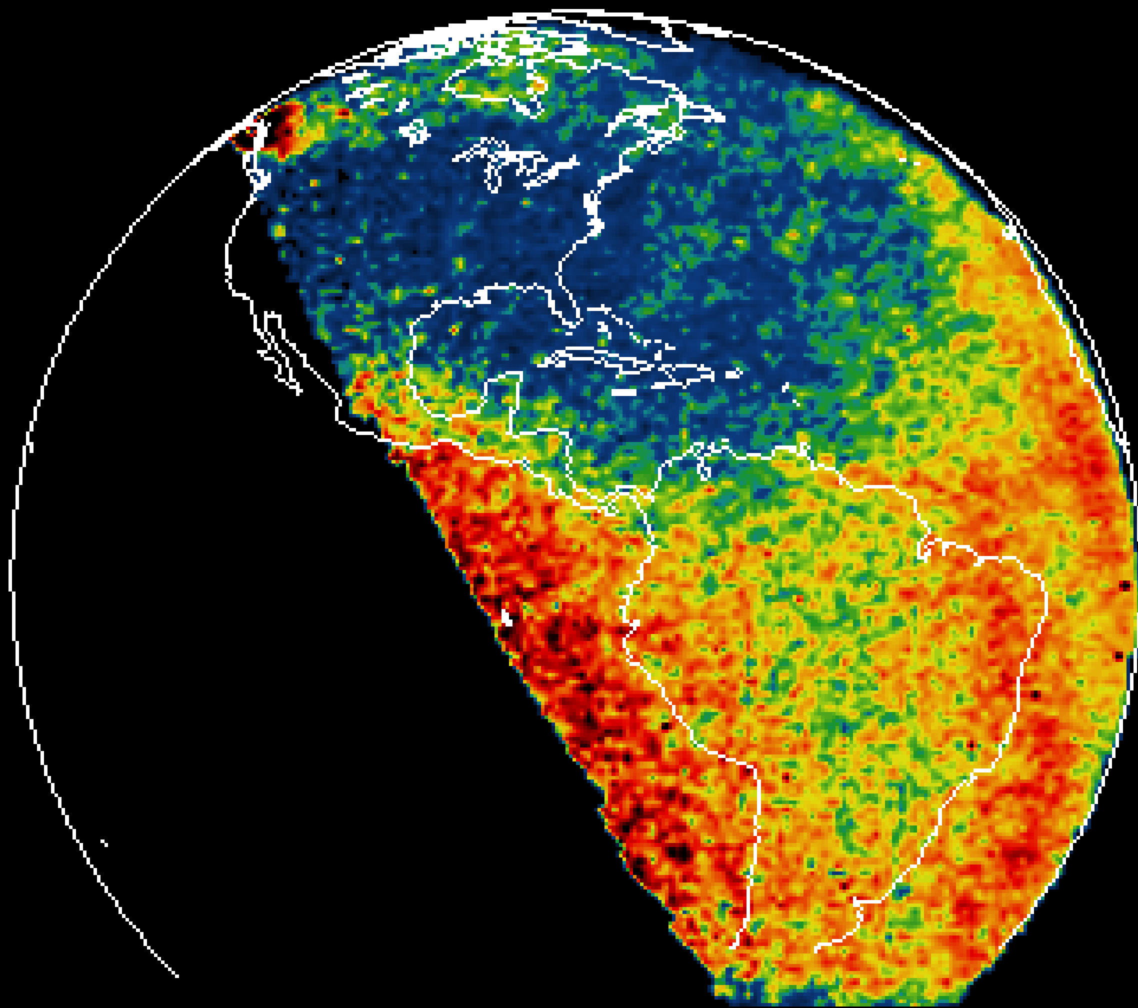


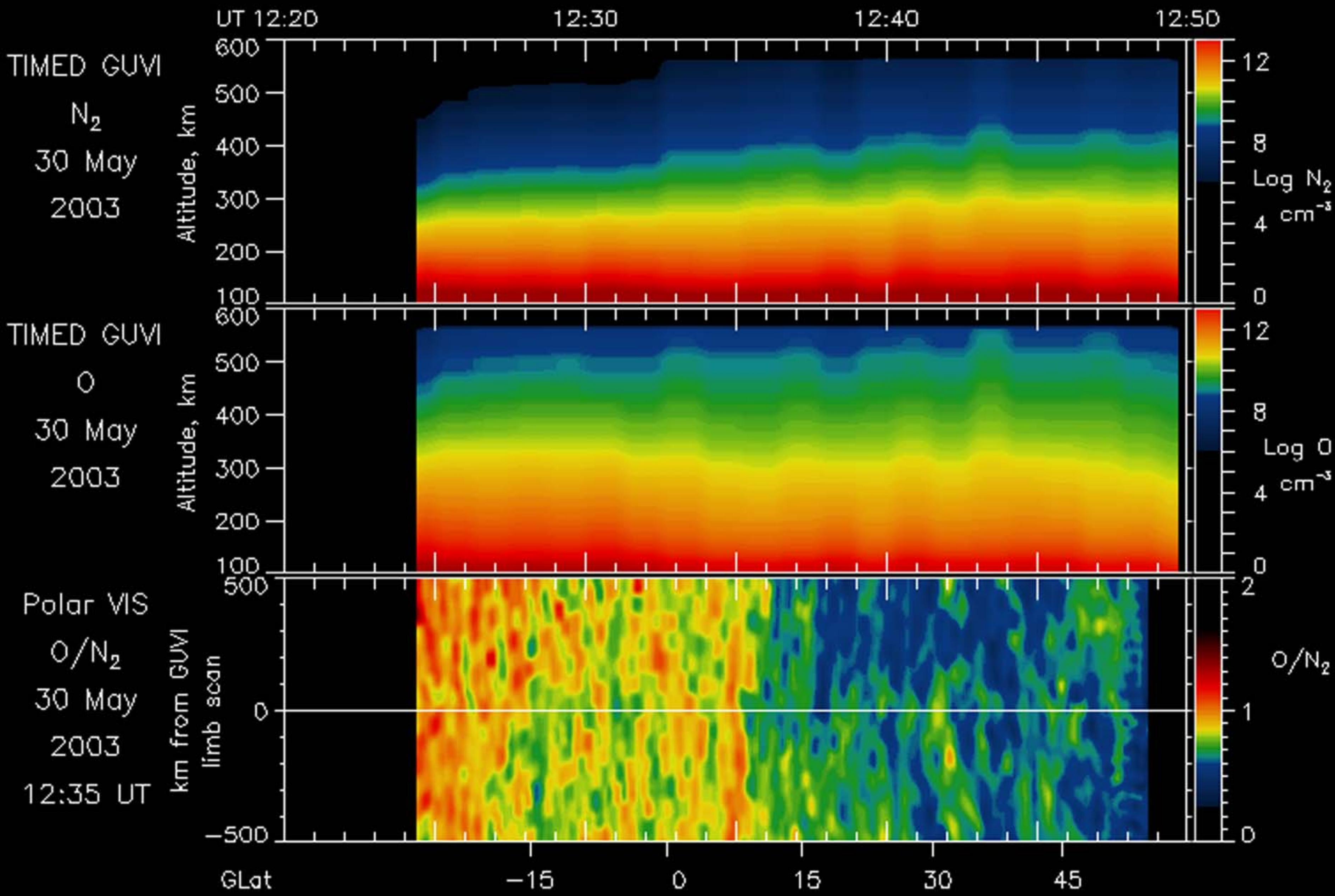
UT
14:30
14:40
14:50
TIMED GUVI
O/N2
26 May
2003
Altitude, km
600
500
400
300
200
100
4
2
0
−2
−4
Log
O/N2
Polar VIS
O/N2
26 May
2003
14:59 UT
km from GUVI
limb scan
500
0
−500
2
1
0
O/N2
GLat
−30
−15
0
15
30
45

VIS Earth Camera

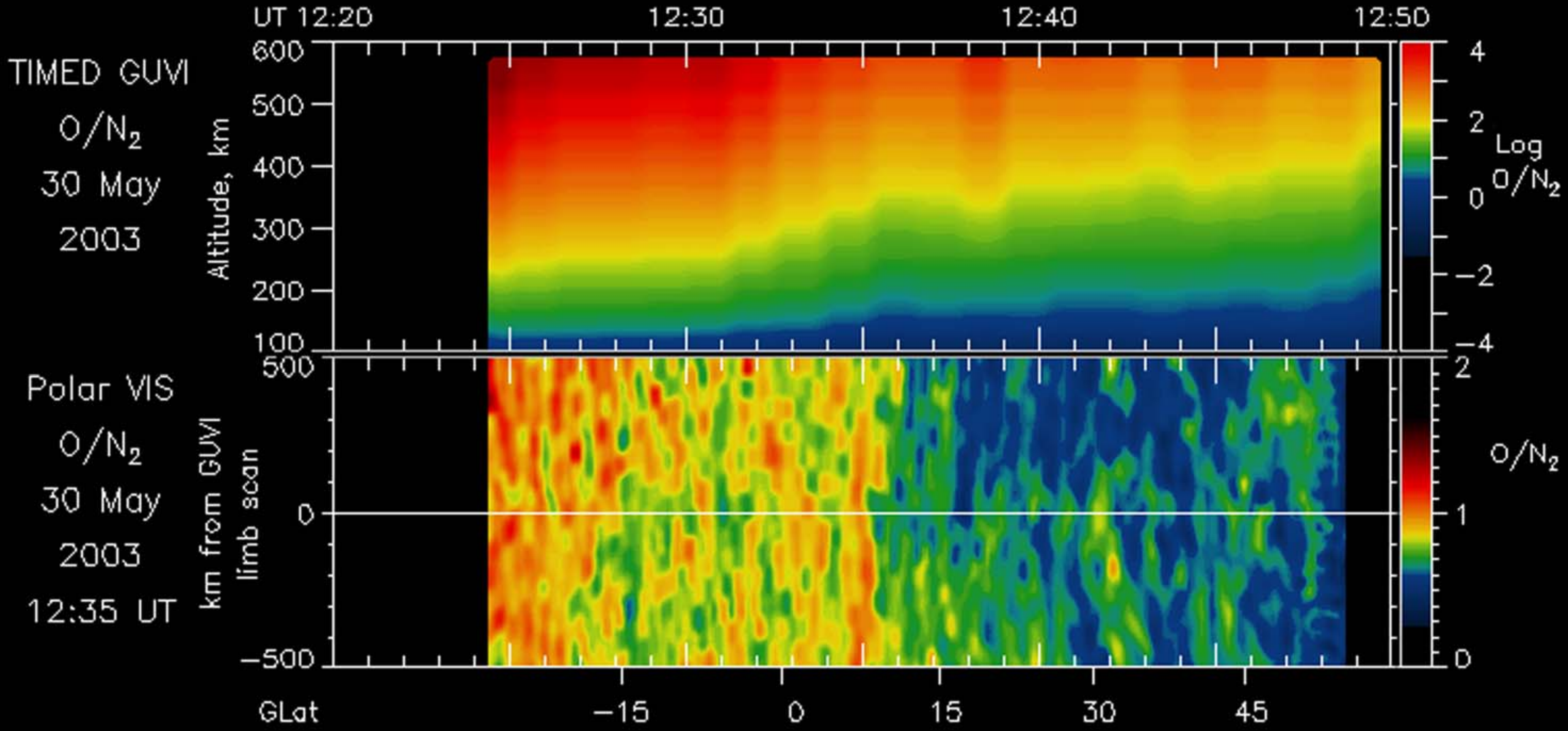
30 May 2003 (03/150)

12:35:04 UT 130.4 nm





UT 12:20
12:30
12:40
12:50
TIMED GUVI
N2
30 May
2003
Altitude, km
600
500
400
300
200
100
12
8
4
0
Log N2
cm-3
TIMED GUVI
O
30 May
2003
Altitude, km
Log O
cm-3
Polar VIS
O/N2
30 May
2003
12:35 UT
km from GUVI
limb scan
500
0
-500
2
1
0
O/N2
GLat
-15
0
15
30
45

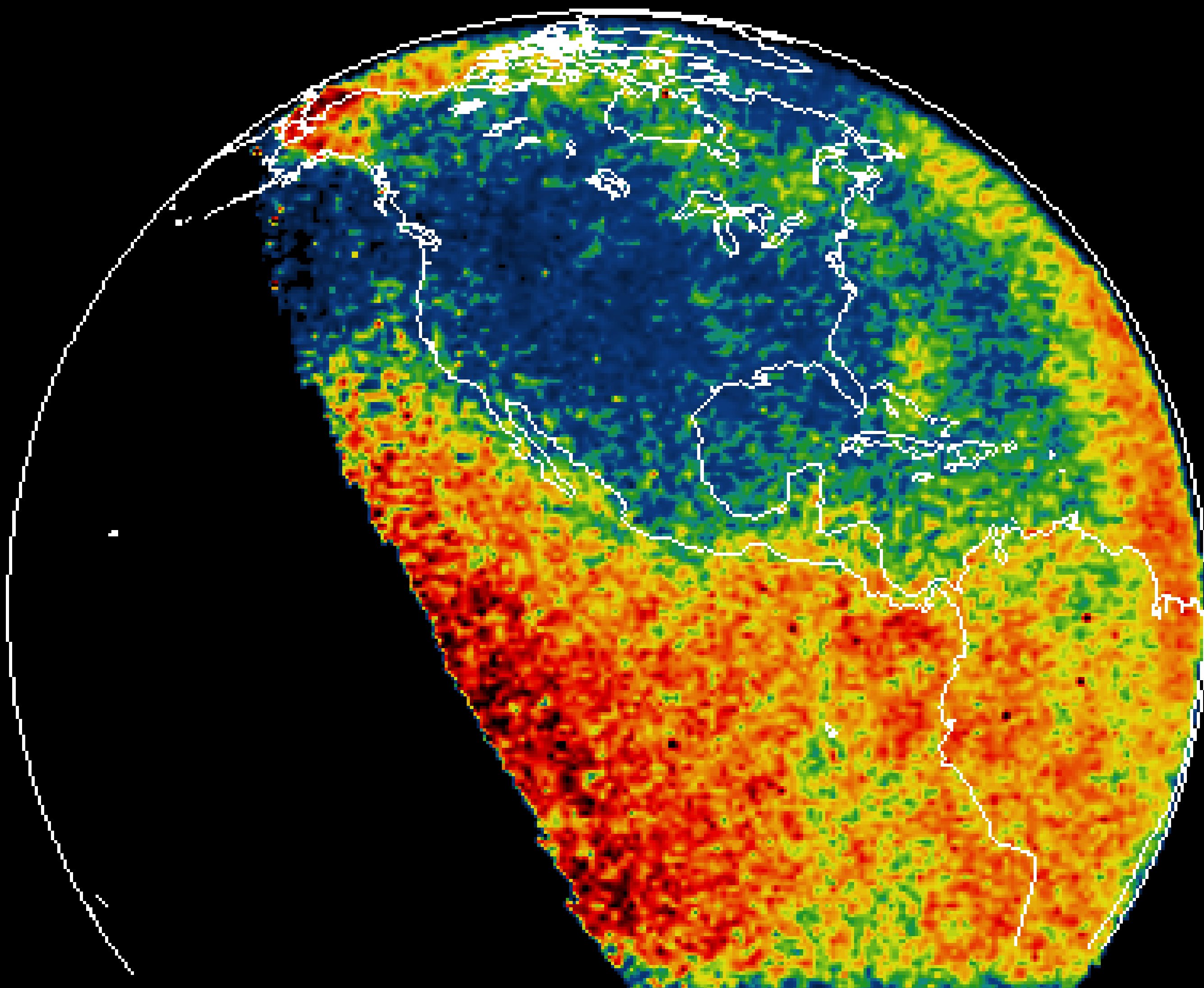


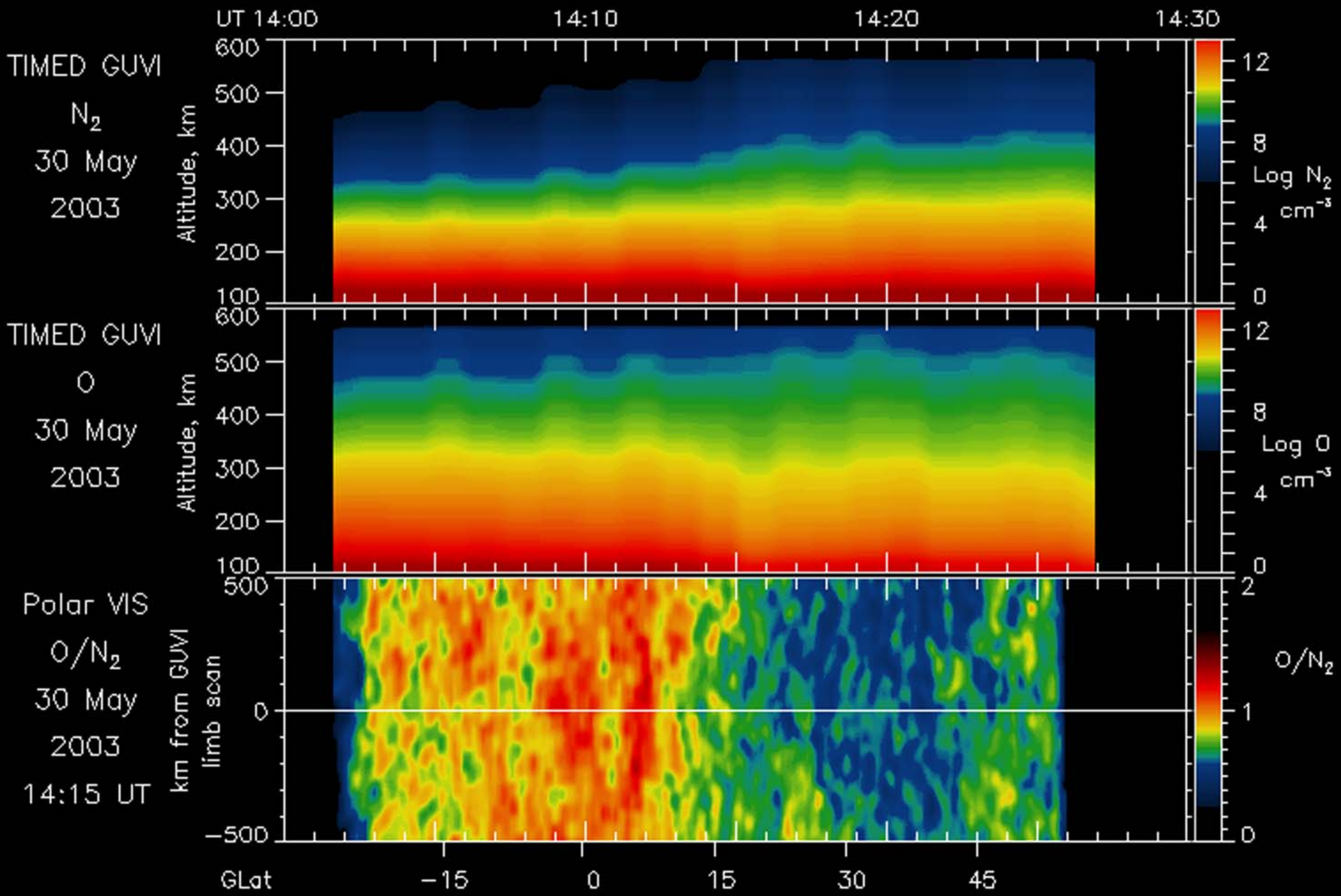
UT 12:20
12:30
12:40
12:50
TIMED GUVI
O/N2
30 May
2003
Altitude, km
600
500
400
300
200
100
4
2
0
−2
−4
Log
O/N2
Polar VIS
O/N2
30 May
2003
12:35 UT
km from GUVI
limb scan
500
0
−500
2
1
0
O/N2
GLat
−15
0
15
30
45

# VIS Earth Camera

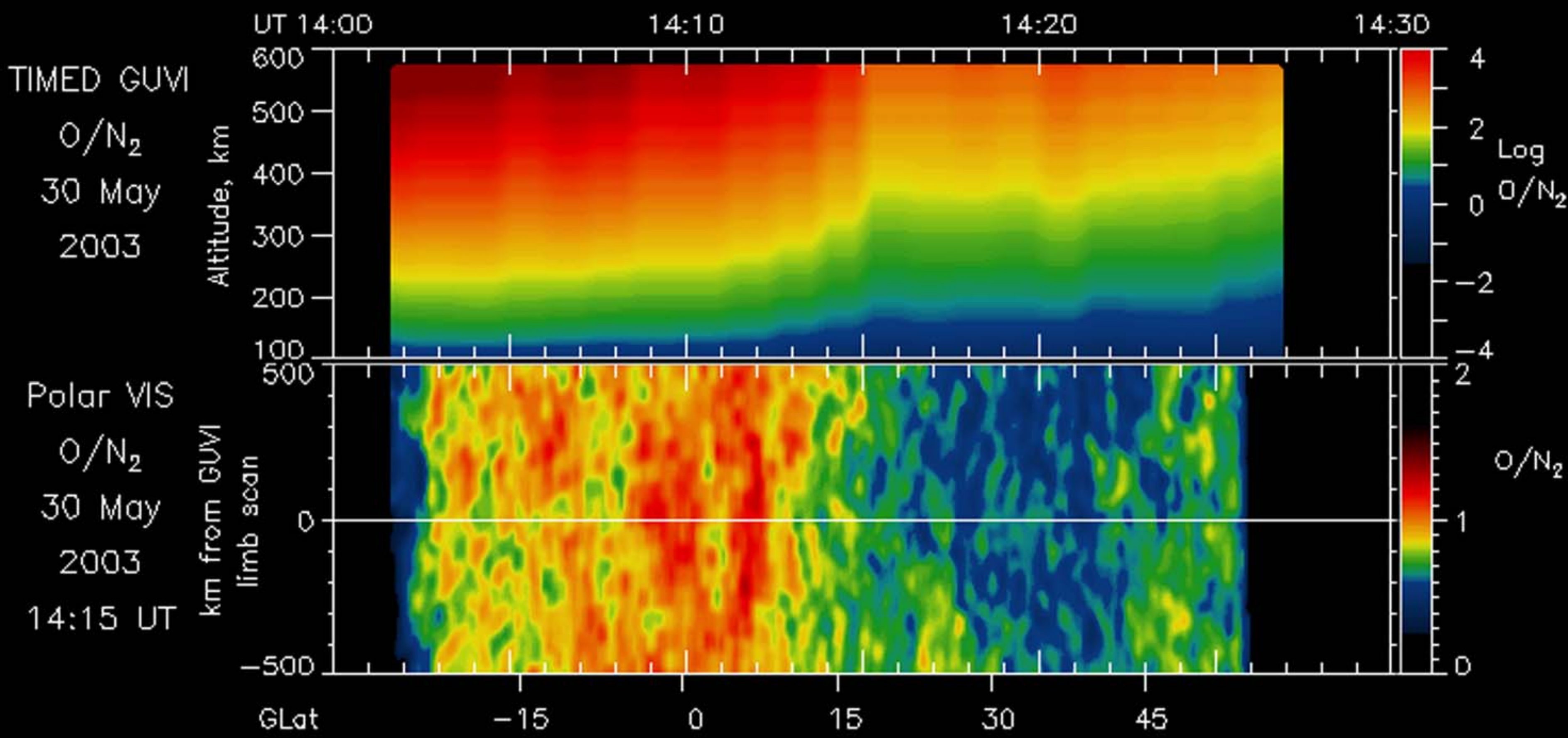
30 May 2003 (03/150)

14:15:34 UT 130.4 nm





UT 14:00
14:10
14:20
14:30
TIMED GUVI
$N_2$
30 May
2003
Altitude, km
600
500
400
300
200
100
12
8
4
0
Log $N_2$
$cm^{-3}$
TIMED GUVI
O
30 May
2003
Altitude, km
Log O
$cm^{-3}$
Polar VIS
$O/N_2$
30 May
2003
14:15 UT
km from GUVI
limb scan
500
0
−500
2
1
0
$O/N_2$
GLat
−15
0
15
30
45



TIMED GUVI
O/N2
30 May
2003
Polar VIS
O/N2
30 May
2003
14:15 UT
UT 14:00
14:10
14:20
14:30
Altitude, km
600
500
400
300
200
100
km from GUVI limb scan
500
0
−500
GLat
−15
0
15
30
45
Log O/N2
4
2
0
−2
−4
O/N2
2
1
0

# Discussion

The vertical altitude profiles derived from the TIMED/GUVI limb scans demonstrate that the regions of low $O/N_2$ observed by the Polar/VIS Earth Camera are due to *both* reduced O density and increased $N_2$ density. In addition the $N_2$ density can be seen to upwell from lower in the atmosphere and subsequently dominate the chemistry of the thermosphere.

# Discussion

The decrease in $O/N_2$ results from heating of the lower thermosphere by direct impact of auroral precipitation and the associated joule heating in the ionosphere. Heated molecular species $N_2$ and $O_2$ in the lower thermosphere upwell to higher altitudes. Subsequently, these molecular species are carried to middle latitudes by thermospheric winds where they cool and dissipate. (Strickland et al., 1999 and references therein.)

# Discussion

- Increases in $N_2$ and $O_2$ molecular densities in the lower thermosphere reduce the ambient O density through the 3-body reactions
  - $O + O + N_2 \rightarrow O_2 + N_2$
  - $O + O + O_2 \rightarrow O_2 + O_2$
- Increases in $N_2$ and $O_2$ molecular densities in the ionosphere reduce the ionospheric electron density by charge exchange between the molecular and atomic species followed by rapid dissociative recombination.
  - $N_2 + O^+ \rightarrow NO^+ + N$<br>$NO^+ + e^- \rightarrow N + O$
  - $O_2 + O^+ \rightarrow O_2^+ + O$<br>$O_2^+ + e^- \rightarrow O + O$