Comparison of OSIRIS Derived NO Concentrations with Coincident ACE-FTS NO Measurements in the Antarctic Winter Upper Mesosphere

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Abstract - The continuum produced by the $NO+O(+M) \rightarrow NO_2(+M)+h\nu$ chemiluminescent reaction has been detected in the upper mesospheric dark polar regions by OSIRIS on the Odin spacecraft. Limb radiance profiles of continuum spectra are inverted to obtain volume emission rate altitude profiles. The OSIRIS NO_2 observations, combined with atomic oxygen densities determined from OSIRIS $O_2(b^1\Sigma_g^+-X^3\Sigma_g^-)$ 0-0 band observations, are used to derive NO densities. The measurement uncertainty in NO density averaged over the 85 to 100 km altitude range is approximately 3×10^7 molecules cm^{-3}. The estimated systematic uncertainty of the NO densities derived from OSIRIS observations is approximately 40%. When compared with measured NO densities from coordinated ACE-FTS solar occultation NO observations, those derived from the ACE-FTS observations are approximately 40% lower. A Southern Hemisphere map of derived OSIRIS NO densities is presented to demonstrate the potential of the OSIRIS NO_2 continuum observations.
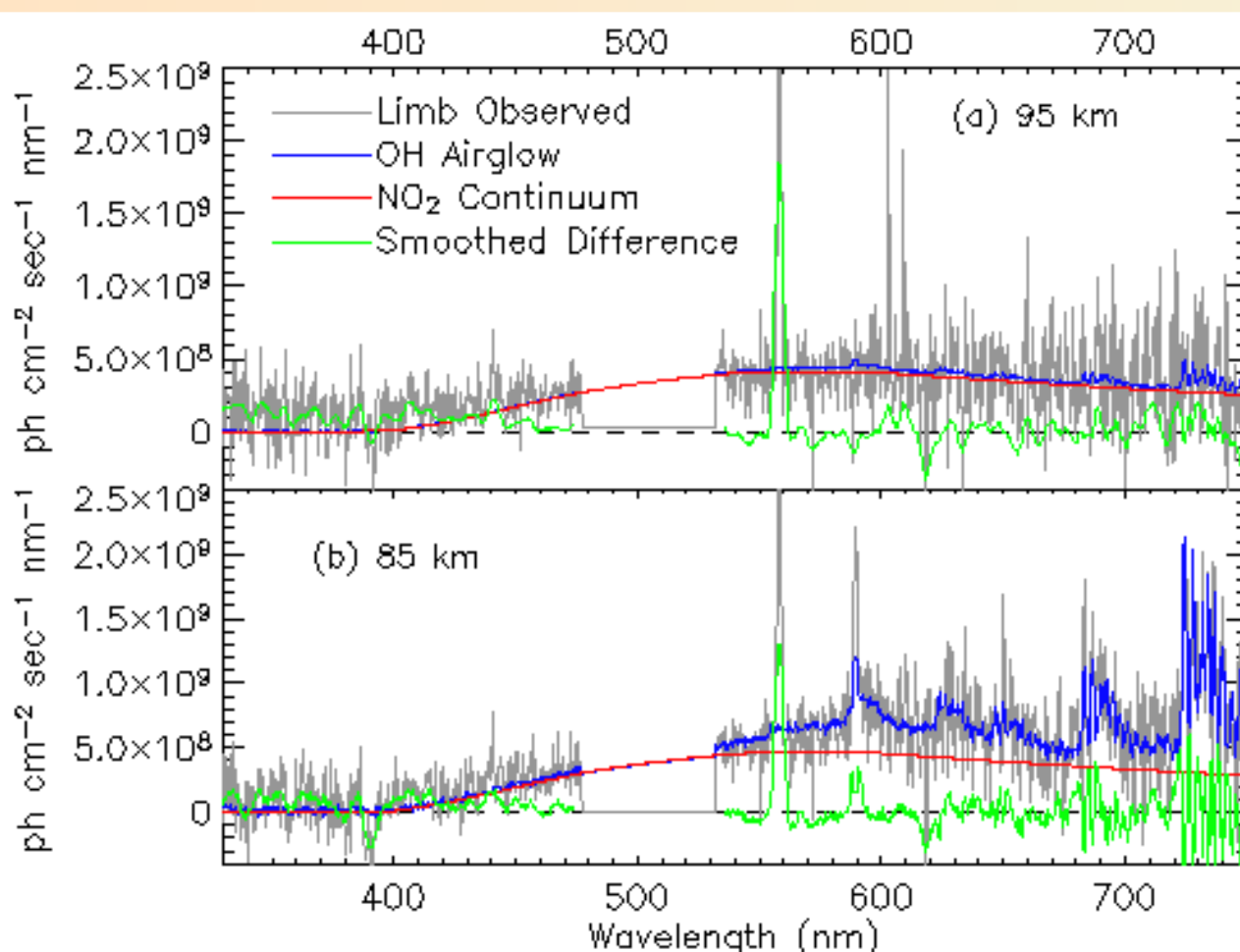
1

The Air Afterglow :
$$NO \ + \ O\,(+M) \ \rightarrow NO_2\,(+M)+h\nu$$
ACE-FTS+OSIRIS → OSIRIS
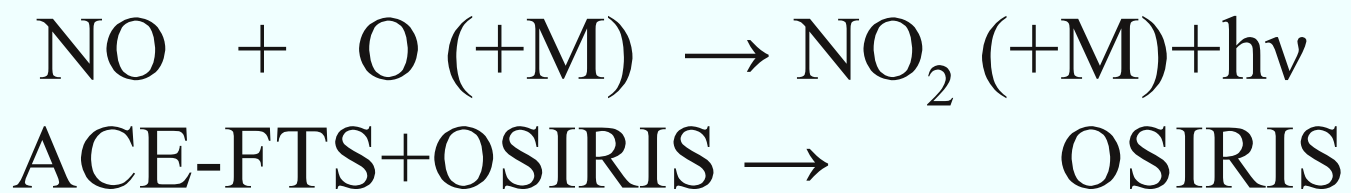
1. ACE-FTS measures [NO] in solar occultation

2. OSIRIS measures [O] via $O_2(b^1\Sigma_g^+ - X^3\Sigma_g^-)$ 762 nm

3. OSIRIS measures NO_2 production rate via $h\nu$

4. Use measured $k_{NO+O(+M)}$ to compare
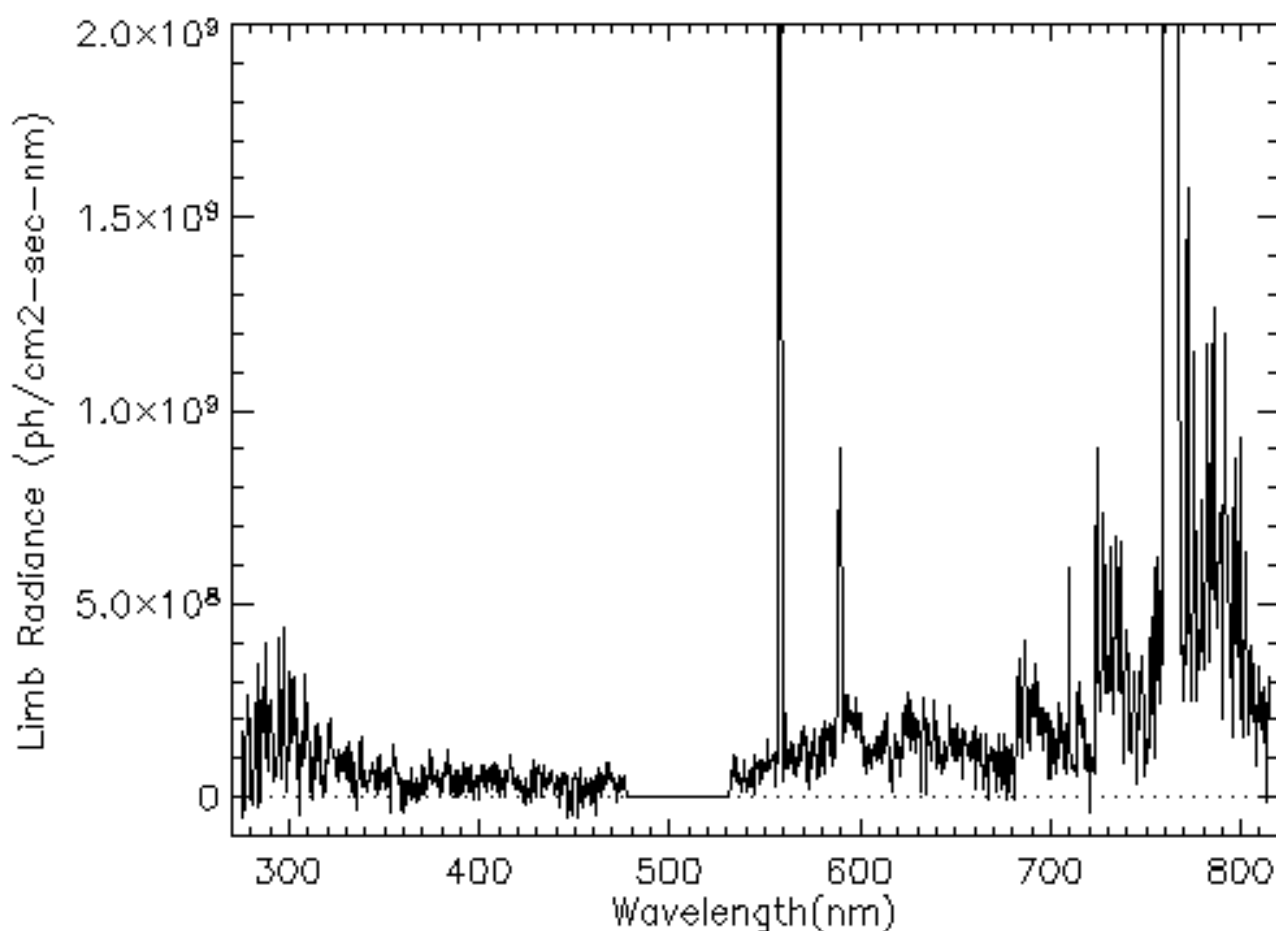
OSIRIS Low Latitude Night Airglow Reference :
- OH
- O_2 Herzberg (UV)

Fitting Reference Spectra to Antarctic Limb :
- Airglow
- NO_2 Continuum

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NO$_2$ Continuum - Spectral Shape and Reaction Rates

Shape - Lab measurements (vs pressure) by Becker *et al*.,1972
Shape - Remeasured by OSIRIS (mesopause), tabulated below
Rates - Total bimolecular and trimolecular - Becker *et al*.,1972
Rates - Total trimolecular - Whytock *et al*.,1976
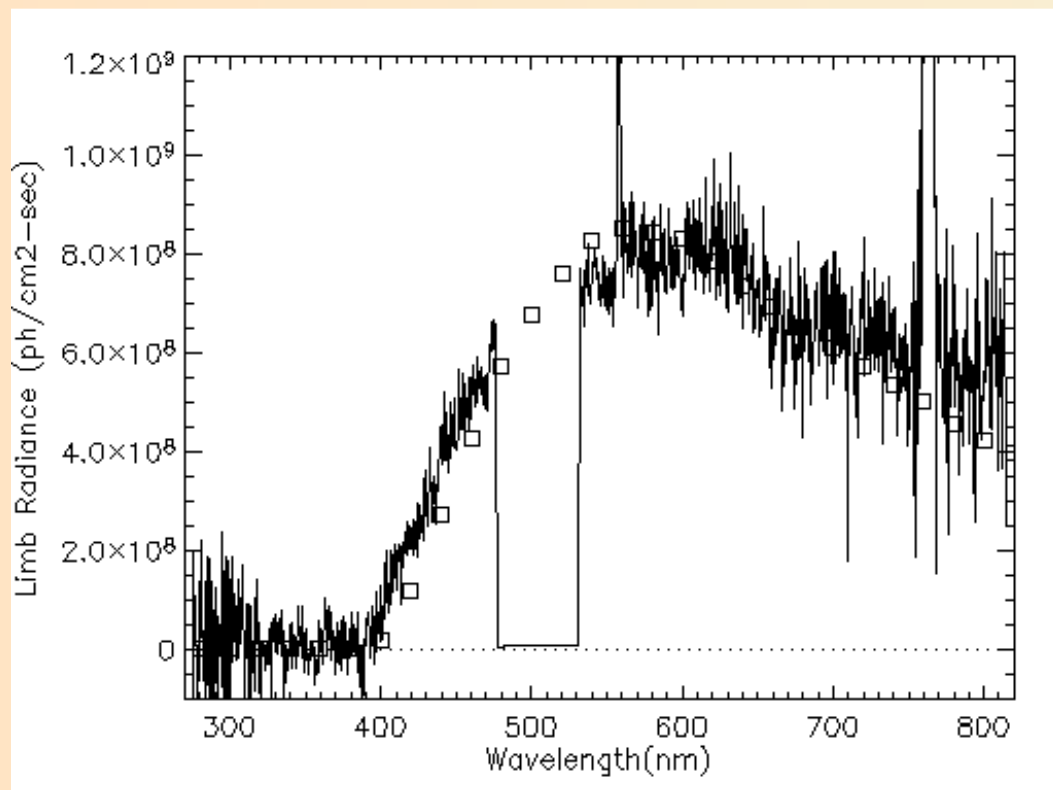
NO$_2$ Continuum
Measured Spectral Shape
(mesopause pressures) :
- Laboratory (□)
- OSIRIS (solid)

Table I – Normalized spectrum of NO+O→NO$_2$+hv chemiluminescent reaction rate measured by OSIRIS. Numbers in brackets near 500 nm are interpolated over spectral order sorter region.

Wavelength (nm)	Normalized Rate	Wavelength (nm)	Normalized Rate	Wavelength (nm)	Normalized Rate
360	0.00	520	(0.88)	680	0.79
380	0.01	540	0.94	700	0.74
400	0.10	560	0.98	720	0.70
420	0.26	580	1.00	740	0.65
440	0.44	600	0.99	760	0.61
460	0.63	620	0.96	780	0.56
480	0.75	640	0.90	800	0.51
500	(0.82)	660	0.85	820	0.49

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OSIRIS NO$_2$ Altitude Profile
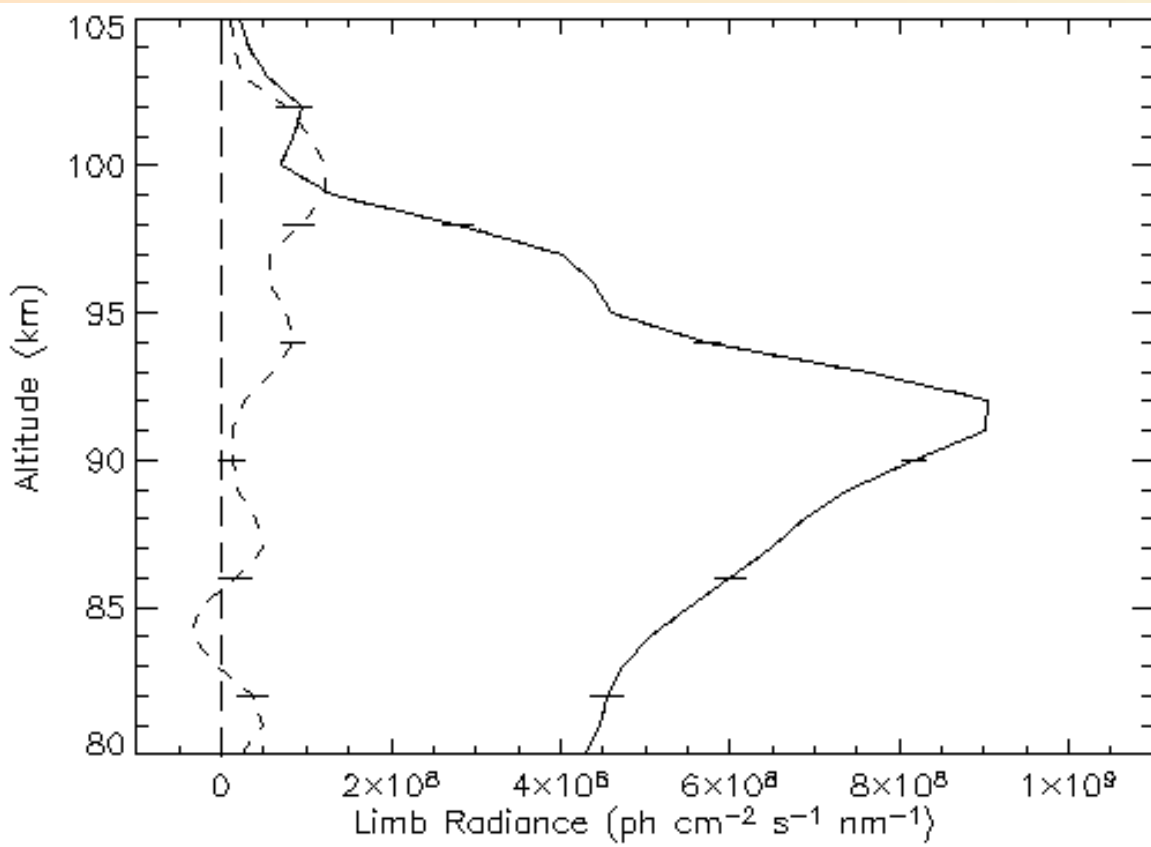
NO$_2$ Continuum
Limb Radiance
9 May 2005
29° south (dash)
75° south (solid)
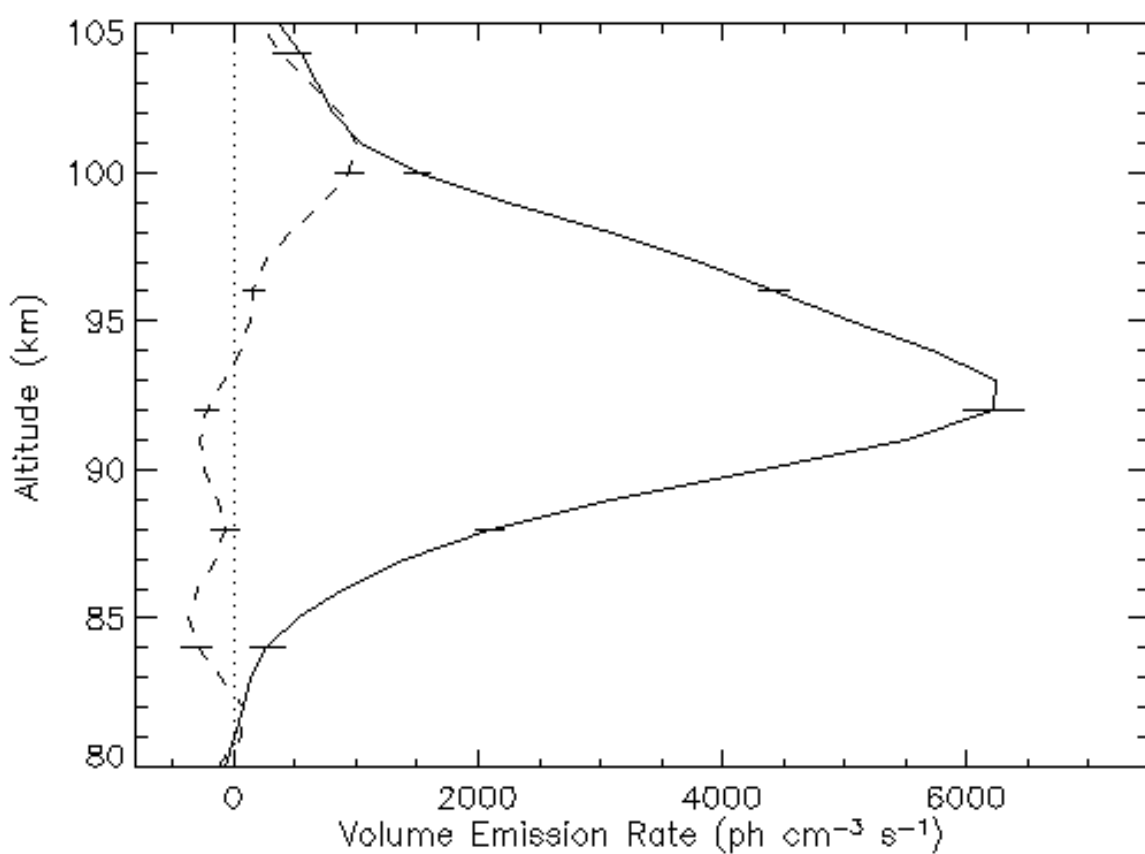
NO$_2$ Continuum
Volume Emission
Rate
9 May 2005
29° south (dash)
75° south (solid)
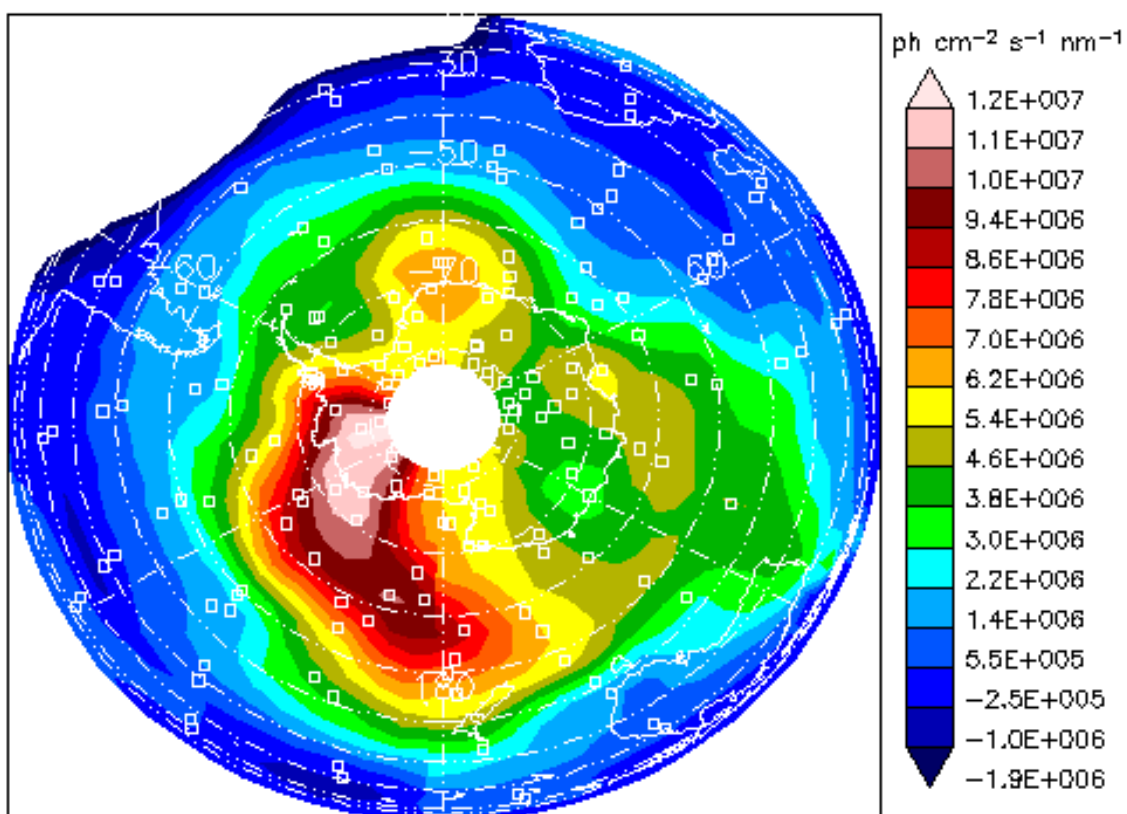
NO$_2$ Continuum
Southern
Hemisphere Map
8-9 May 2005
Referred to
Zenith at 580 nm

4

OSIRIS Observed $O_2(b^1\Sigma_g^+ - X^3\Sigma_g^-)$ 762 nm
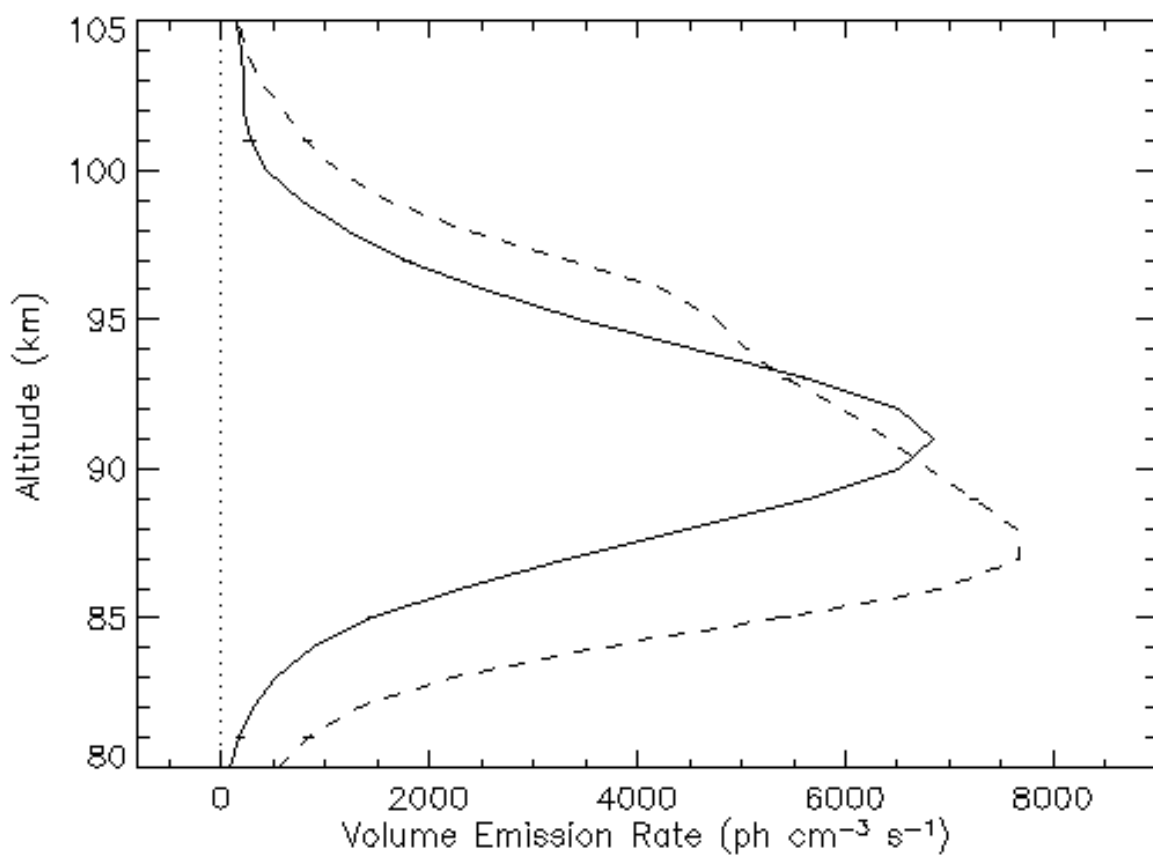
O$_2$ VER Profile
9 May 2005
29° South (dash)
75° South (solid)
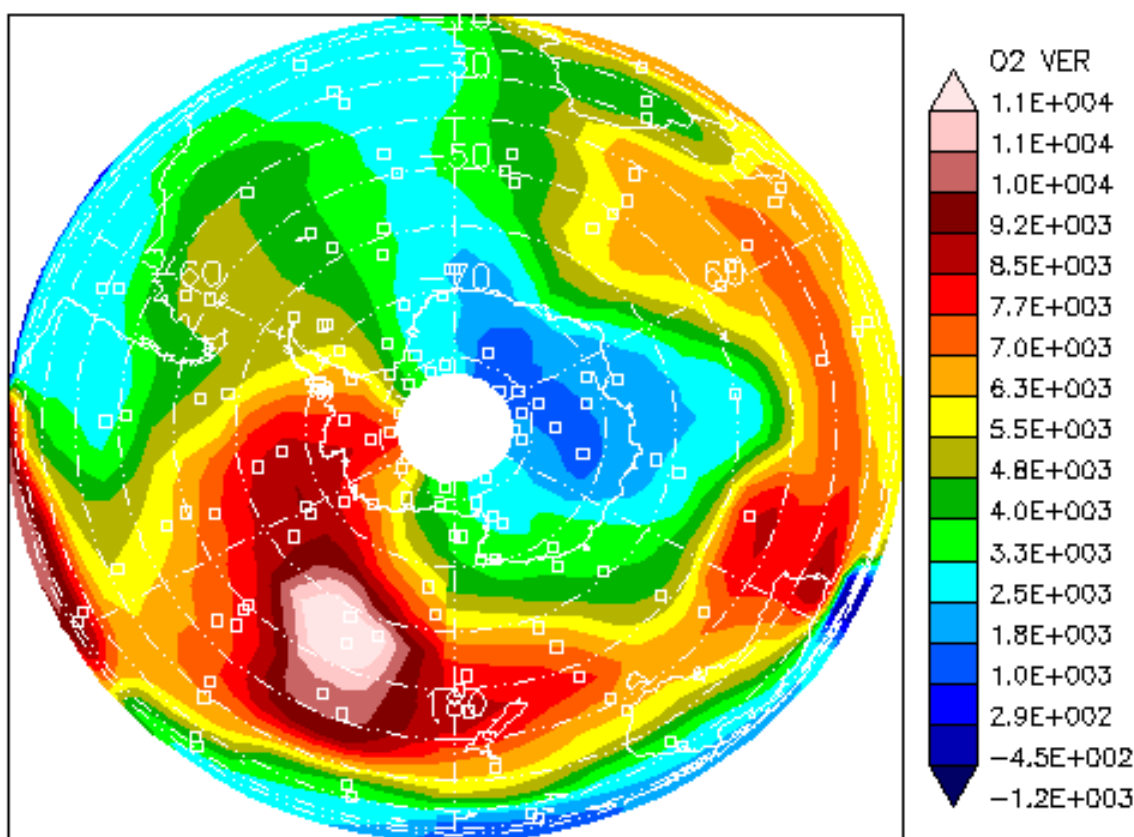
O$_2$ VER
Southern
Hemisphere
8-9 May 2005
90 Km Altitude
Horizontal Slice

O$_2$ VER
Southern
Hemisphere
8-9 May 2005
75° South Zonal
Vertical Slice

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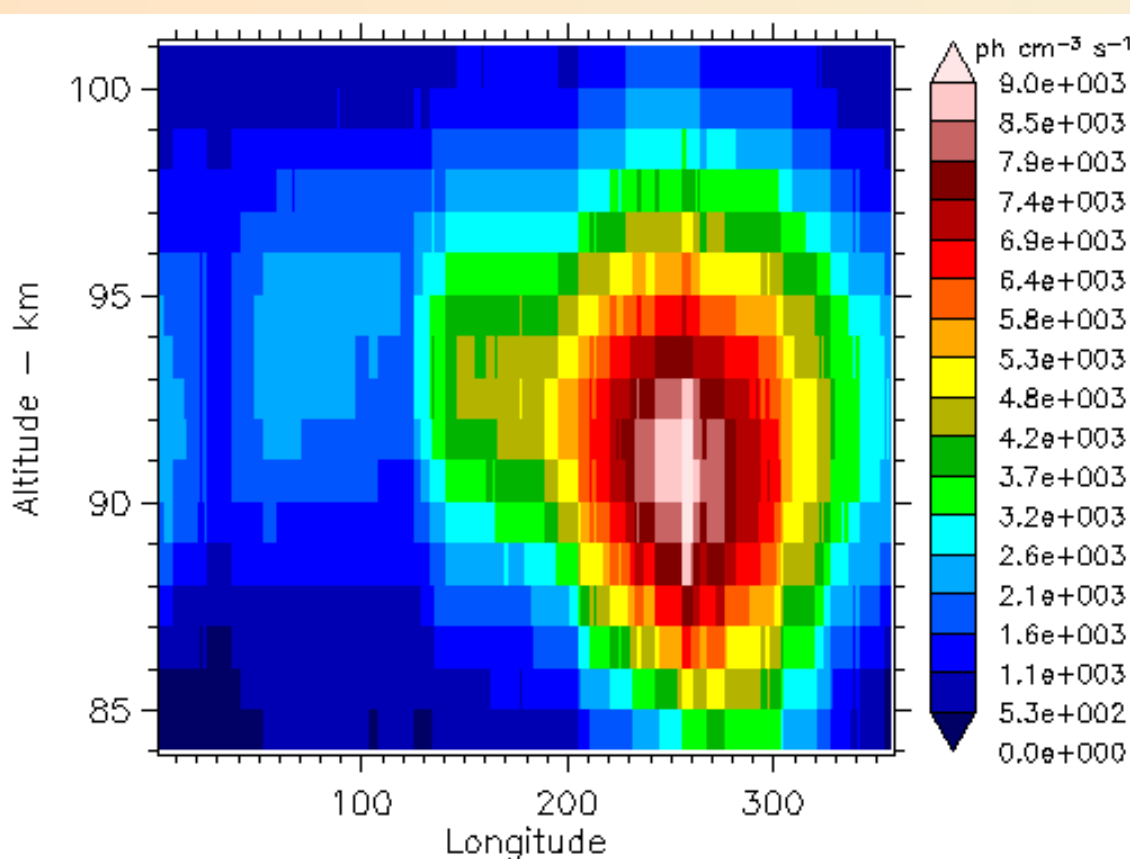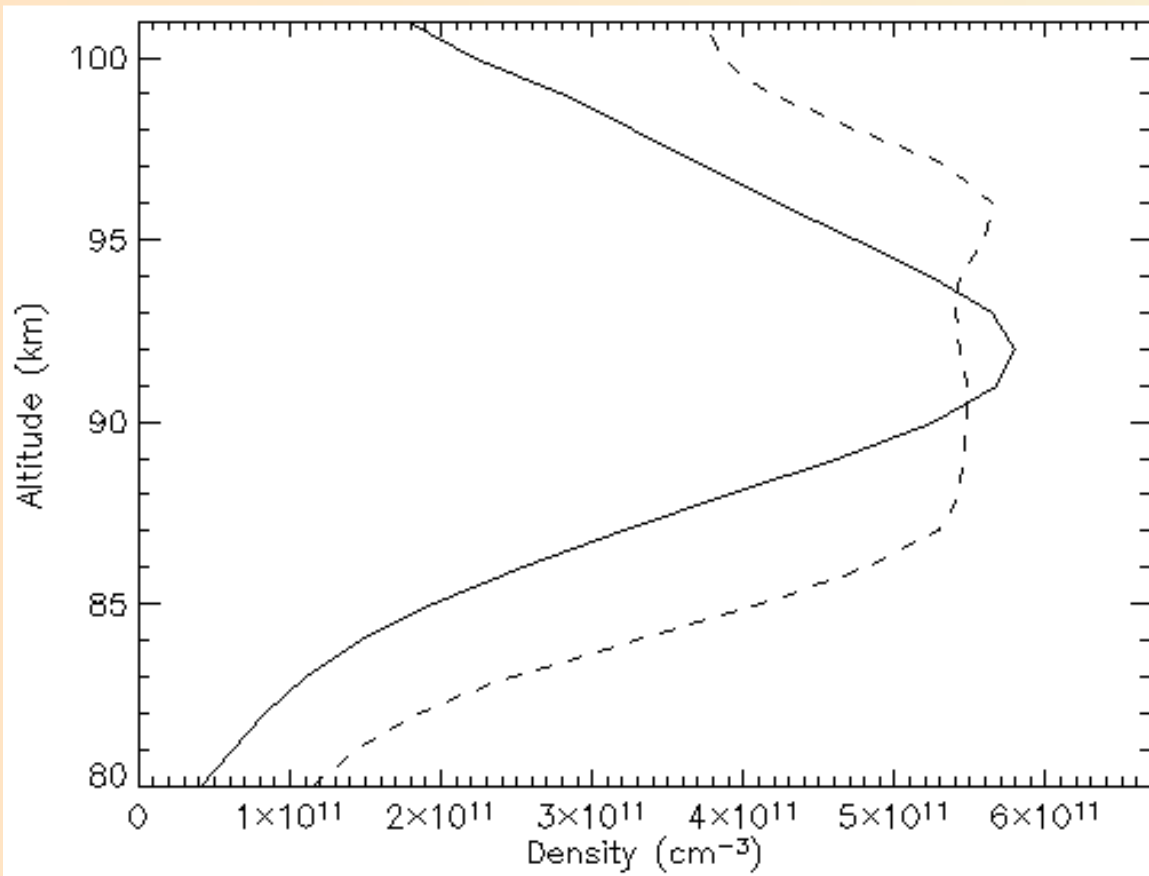
OSIRIS Derived [O]

Derived [O]
9 May 2005
29° South (dash)
75° South (solid)
Syst. Err. ~40%
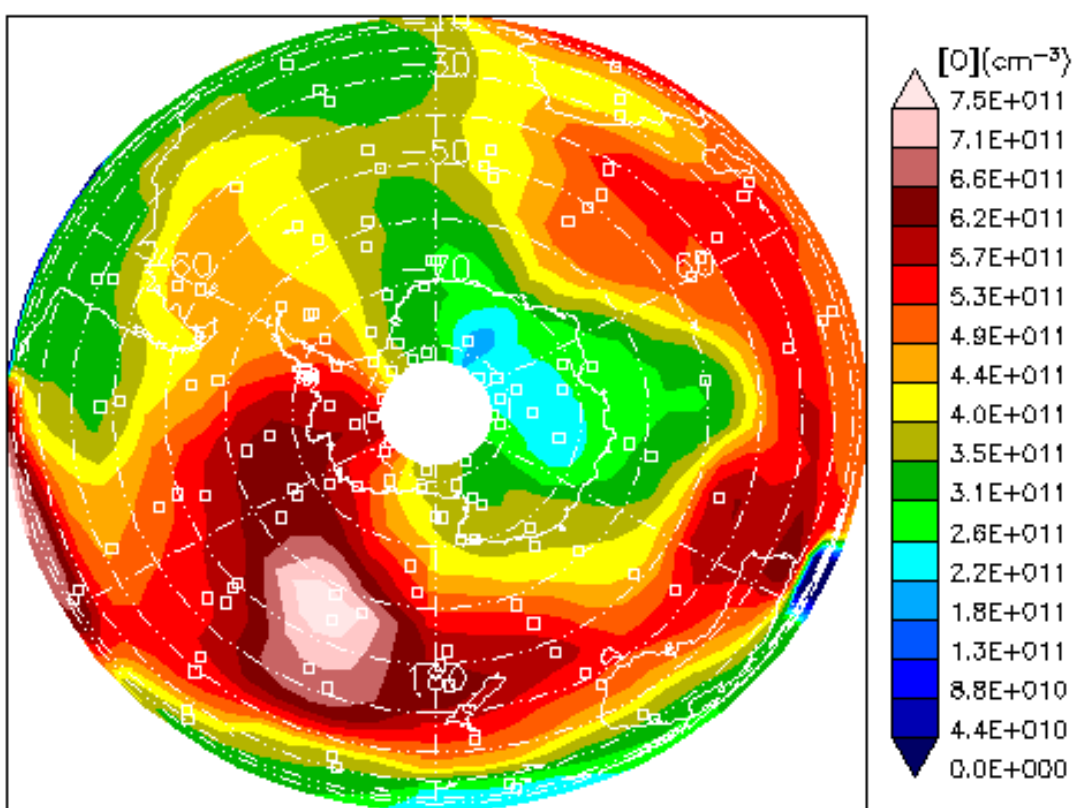
Derived [O]
Southern
Hemisphere
8-9 May 2005
90 Km Altitude
Horizontal Slice

Derived [O]
Southern
Hemisphere
8-9 May 2005
75° South Zonal
Vertical Slice

6

OSIRIS Derived [NO]

Derived [NO]
9 May 2005
29° South (dash)
75° South (solid)
Sys.Err. ~40%
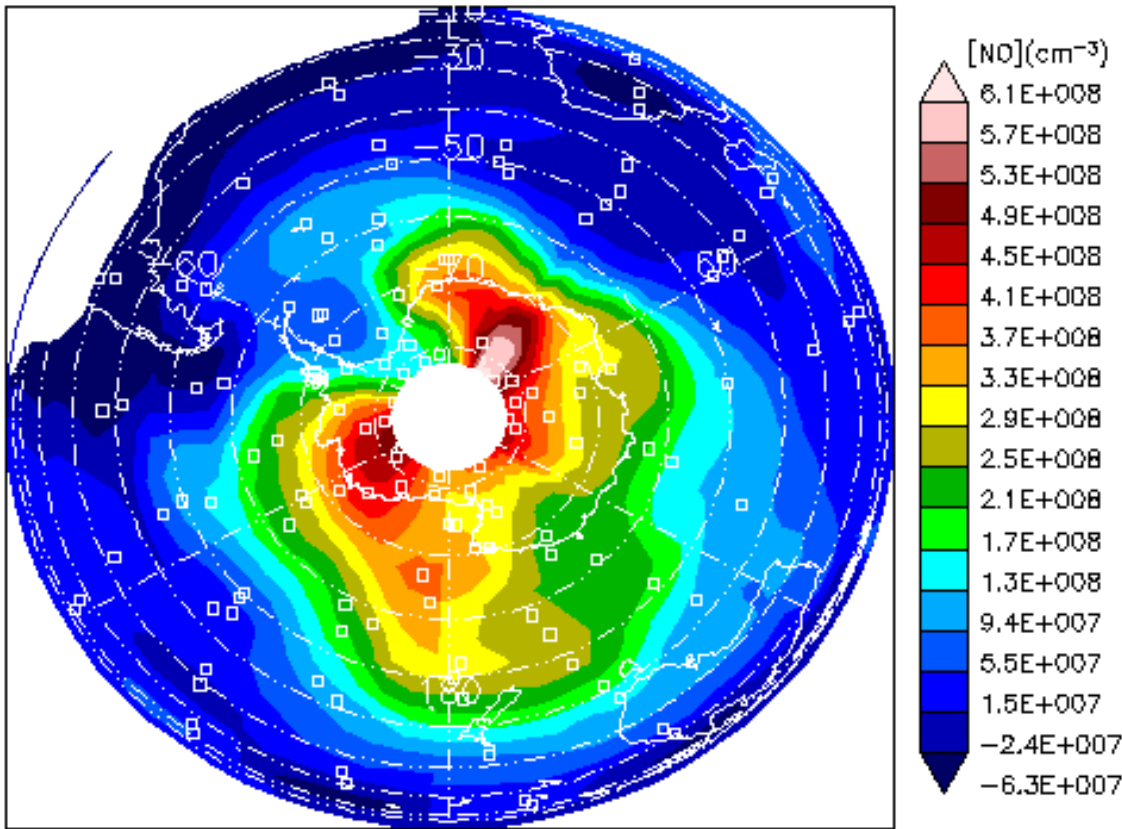
OSIRIS Derived
[NO] Southern
Hemisphere
8-9 May 2005
90 Km Altitude
Horizontal Slice
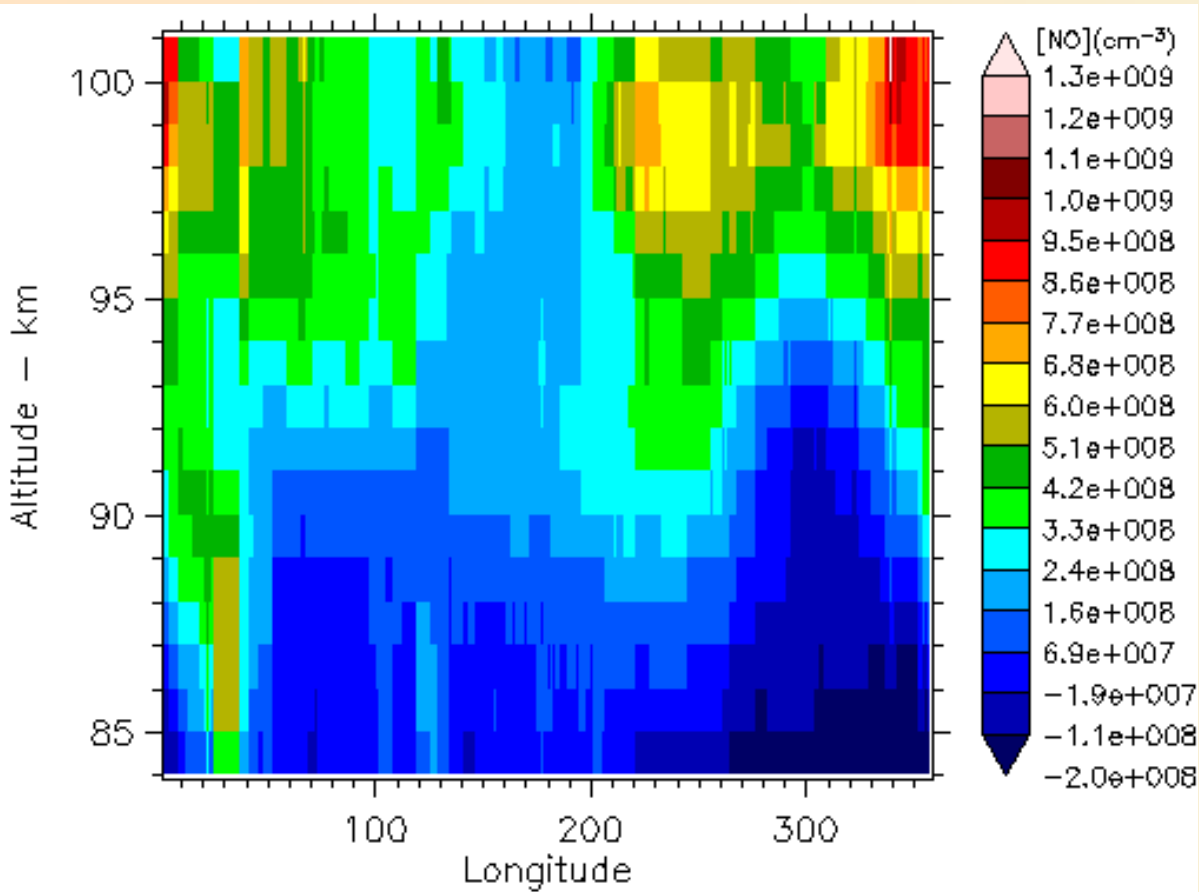
OSIRIS Derived
[NO] Southern
Hemisphere
8-9 May 2005
75° South Zonal
Vertical Slice

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Comparison with ACE-FTS Measured [NO]

ACE-FTS Tracks Solar Occultation, Sunrise and Sunset
Approximately Constant Latitude Over Single Day
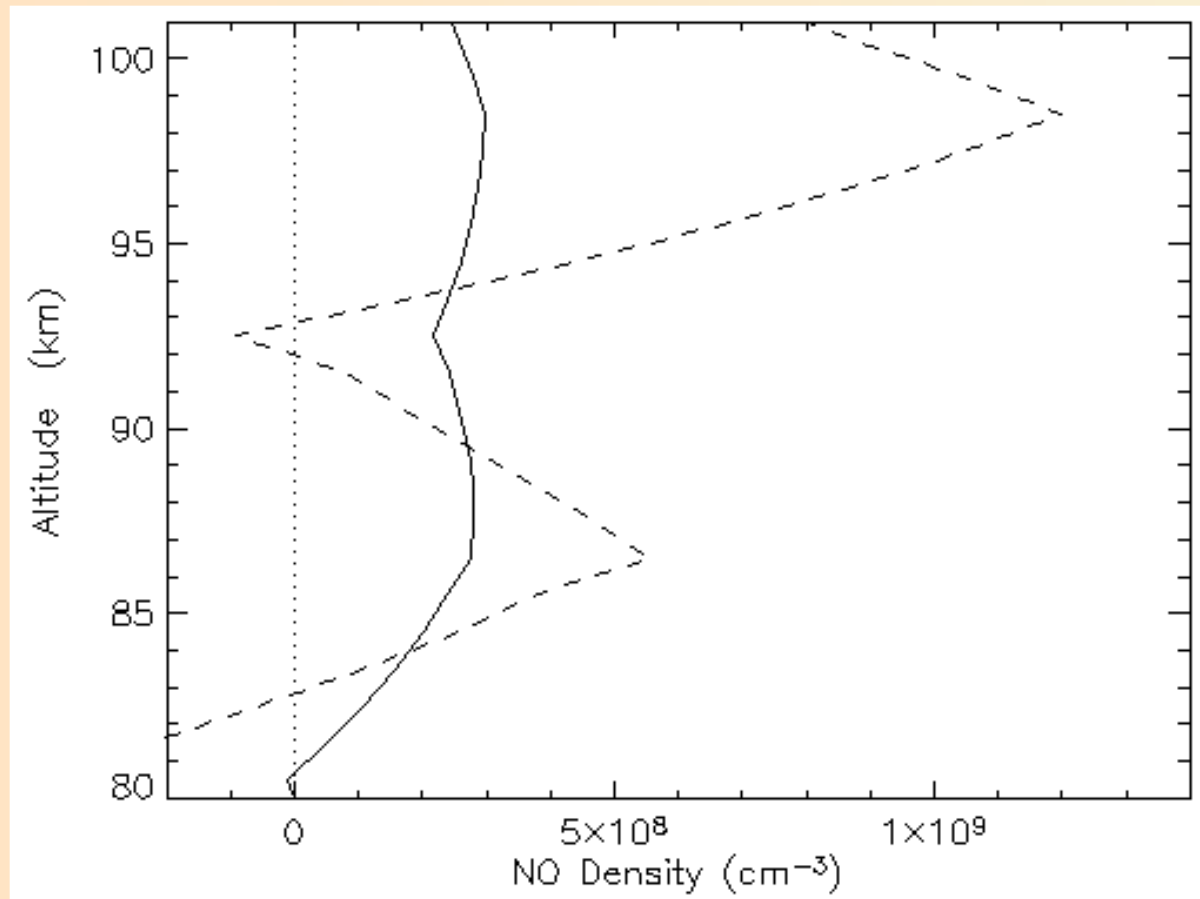
ACE-FTS [NO]
Sunset Examples
9 May 2005
67° South Latitude
Solid - 136° East
Dash - 87° East
Syst. Err ~ 10%
Prec.< 5×10^7 cm^{-3}

For OSIRIS vs ACE-FTS [NO] Comparison :
Data from Antarctic winters 2004 to 2007
Coincidence Criteria : 3° Latitude (50 South to 70 South),
10° Longitude, 5 Hours in Time
[NO] Averaged from 85 km to 100 km
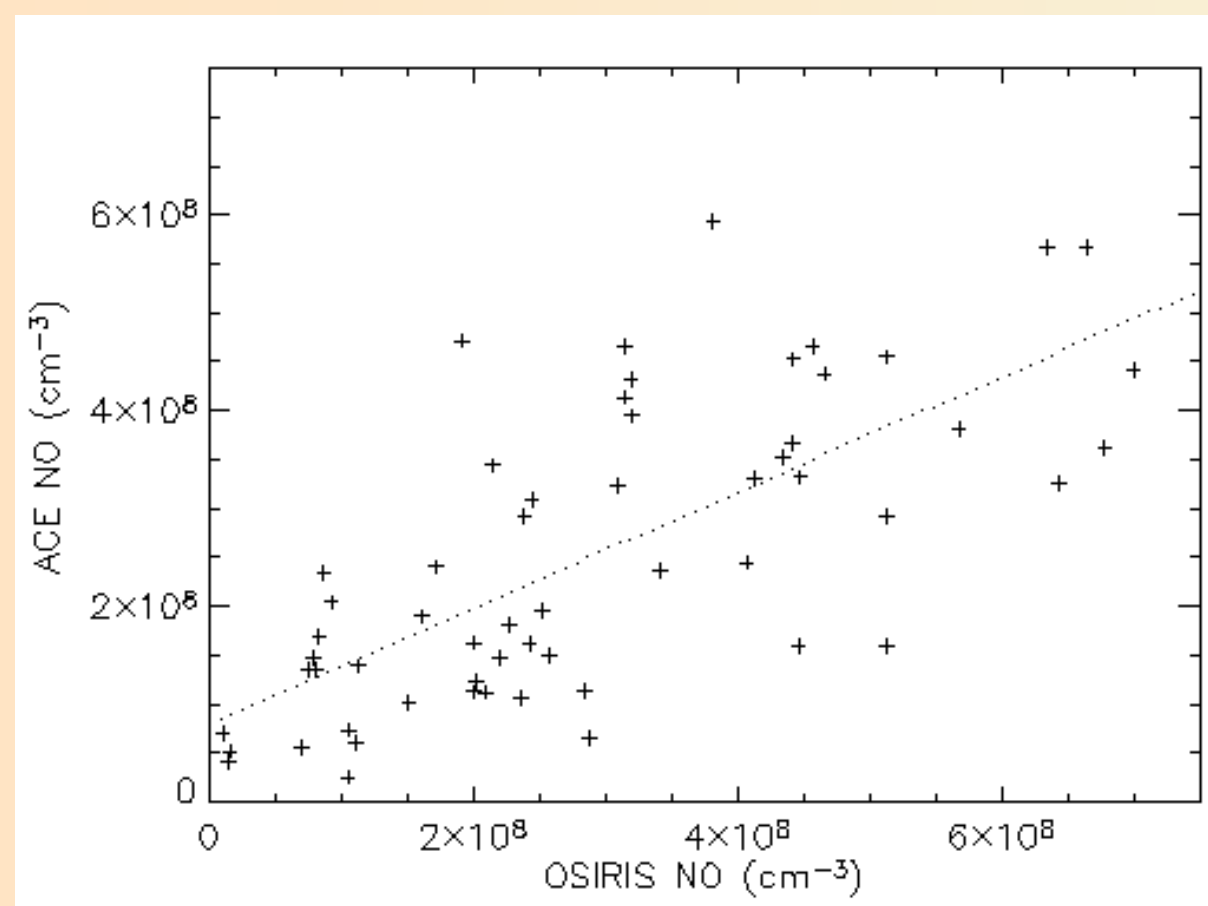
ACE vs OSIRIS
[NO]
85 to 100 Km Avg.
2004 to 2007
Slope 0.59
Syst. Error ~40%
Corr. Coeff. = 0.71
$R^2 = 0.50$
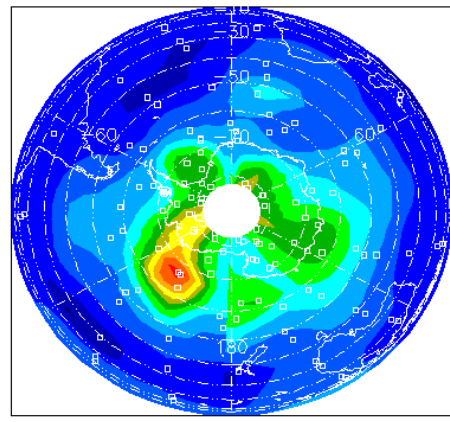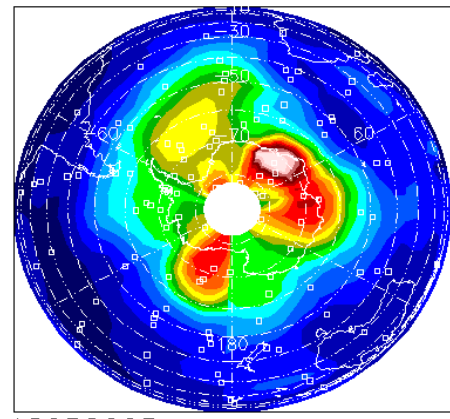
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OSIRIS NO$_2$

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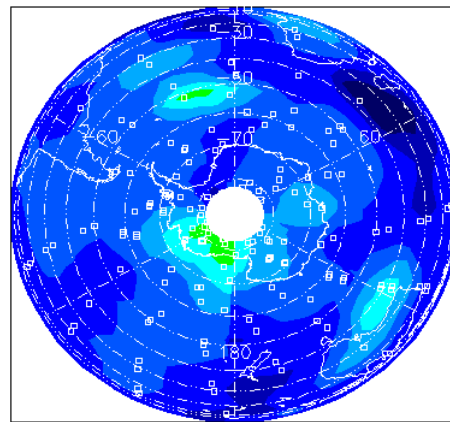
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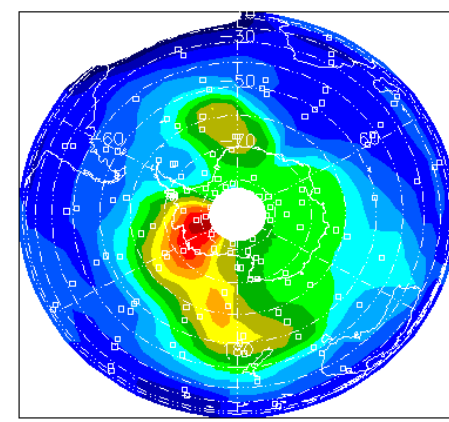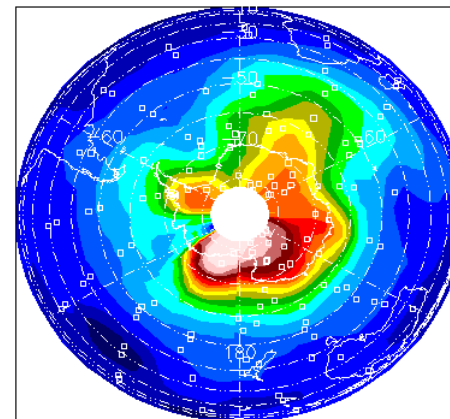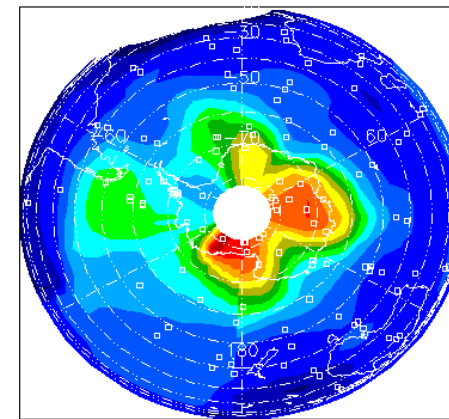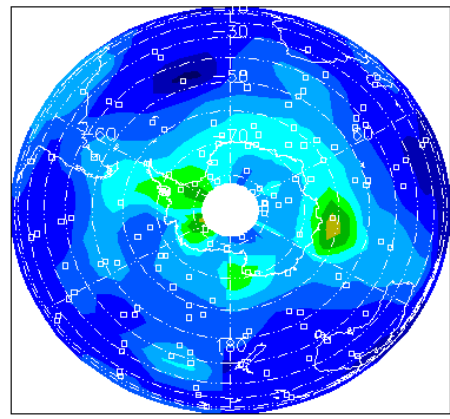
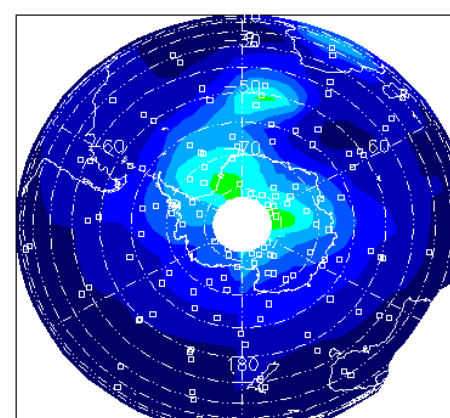09052005

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27052005

05062005

14062005

23062005

02072005

14072005

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OSIRIS O$_2$ 762 nm

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30042005

09052005

18052005

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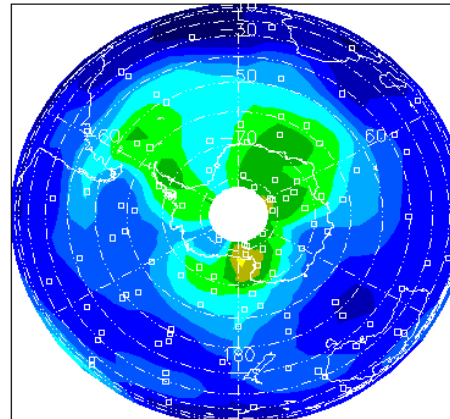
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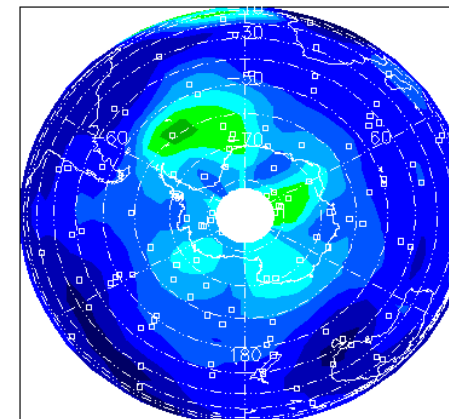
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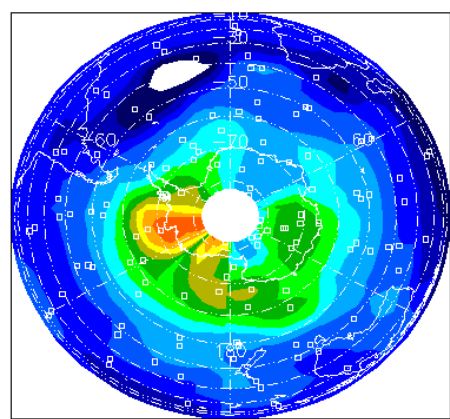
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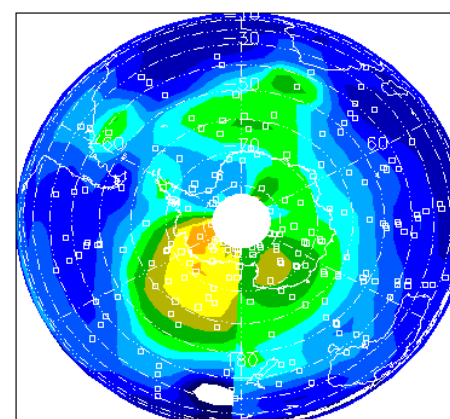
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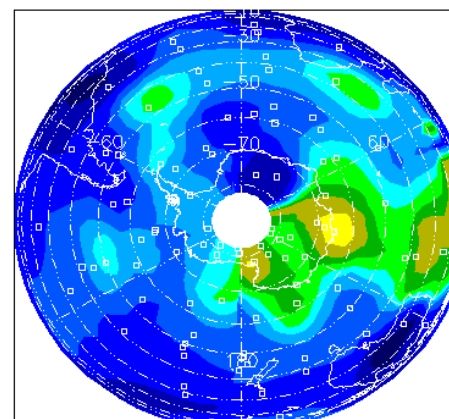
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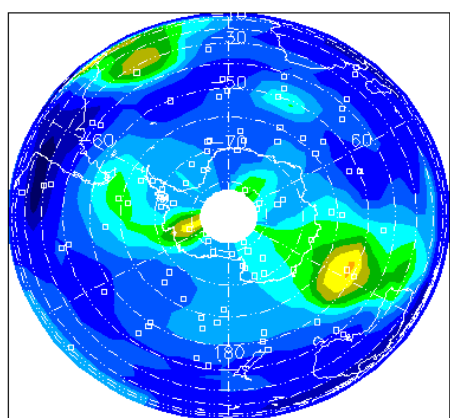
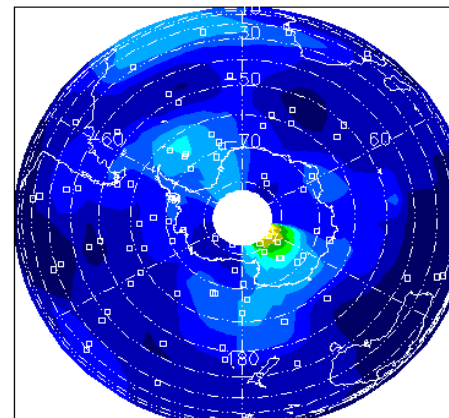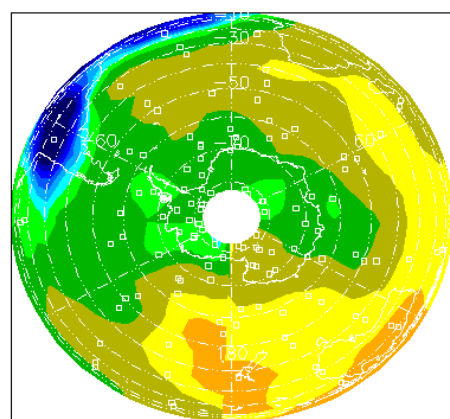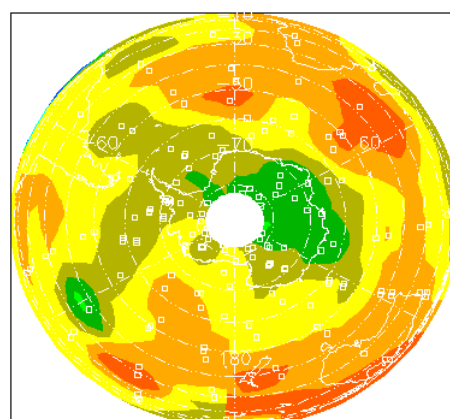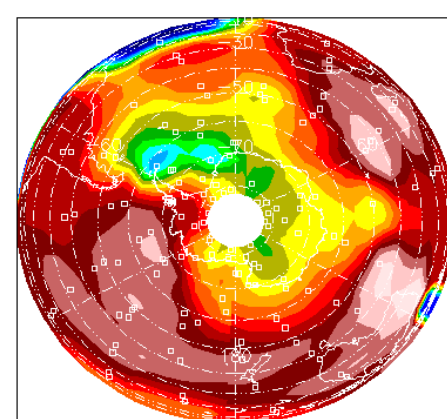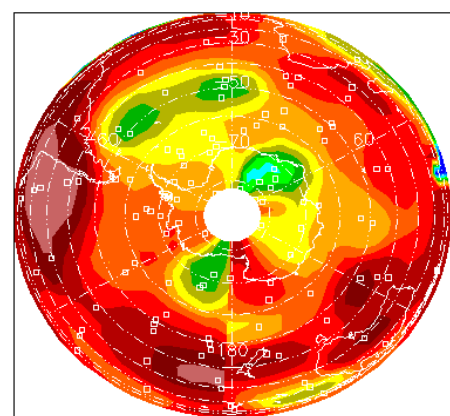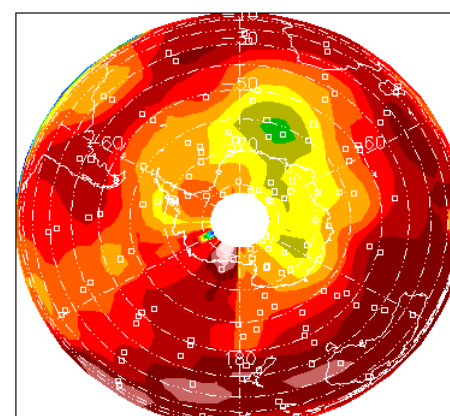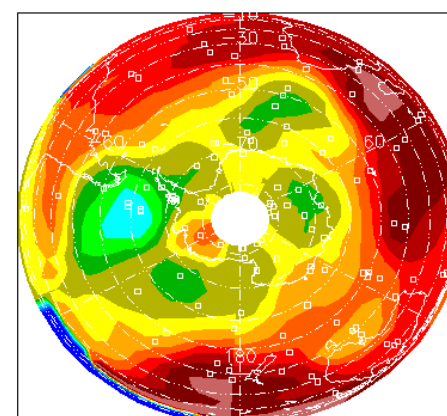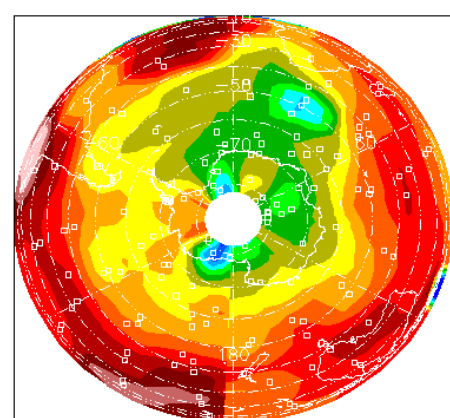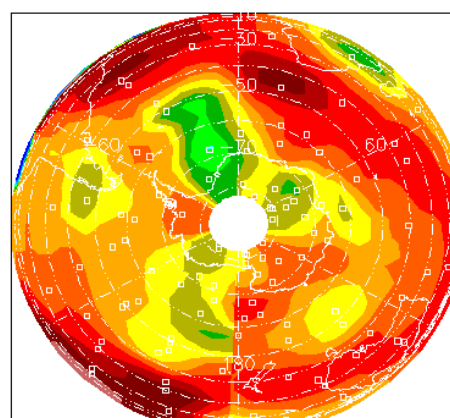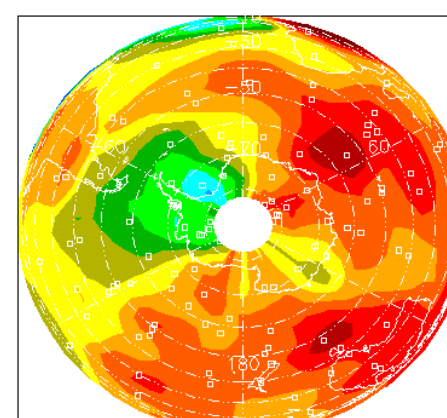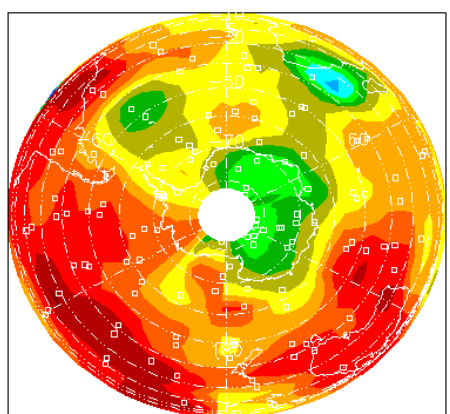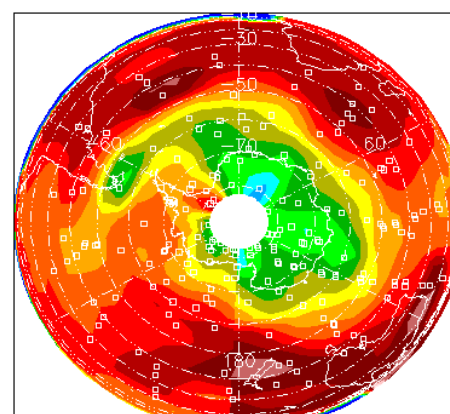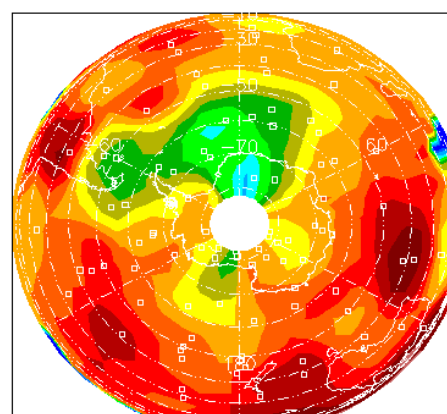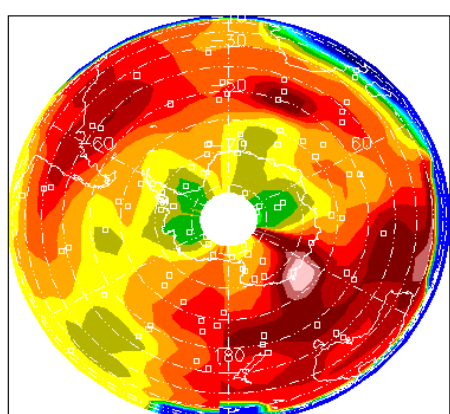23072005
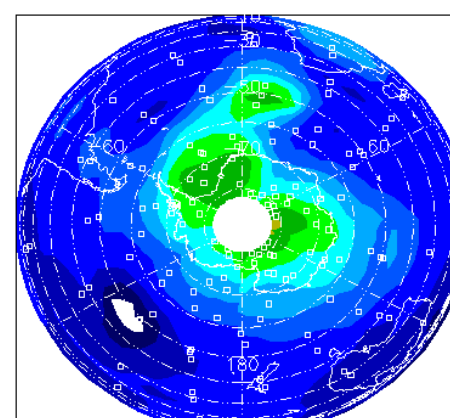
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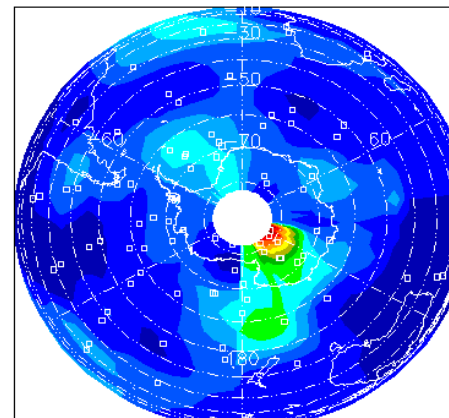
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OSIRIS [NO]

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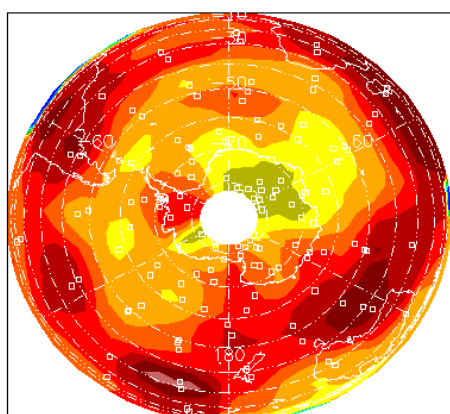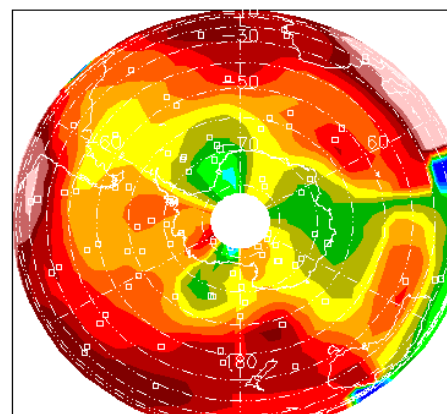14062005

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OSIRIS OH