Nighttime Limb Observations of the Mesosphere and the Lower Thermosphere with OSIRIS on Odin

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•Absorption directly measures the column concentration of the ground or metastable state population.

•Observation can be made in either the limb or the nadir, using scattered light or through occultation.

•The former requires a good radiative transfer model but is tolerant of pointing errors although pointing knowledge is required.

•The latter is self-calibrating but requires accurate pointing in order to capture the target object.

•The observation yields the transmitted spectrum :

•Obviously this technique will only work if there is an illuminating souce.

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At night the approach is to use emission observations.
These measurements yield

$$I = \int V(s)\, ds$$

$$I = \int A\, n(s)\, ds$$

Inversion can yield n(s)

$$\frac{dn}{dt} = P - L$$

$$= k\,[X]\,[Y]\,[Z] - [C]\{A + k_q\,[Q]\}$$

If dn/dt = 0 then measure [C] A, the voume emission, can provides knowledge of [X]
With certain assumptions about other terms in the equation.

During the daytime we can have both absorption and emission and the possibility of albedo effects.

Examples of possible reactions that can yield information are

$O + O + M$

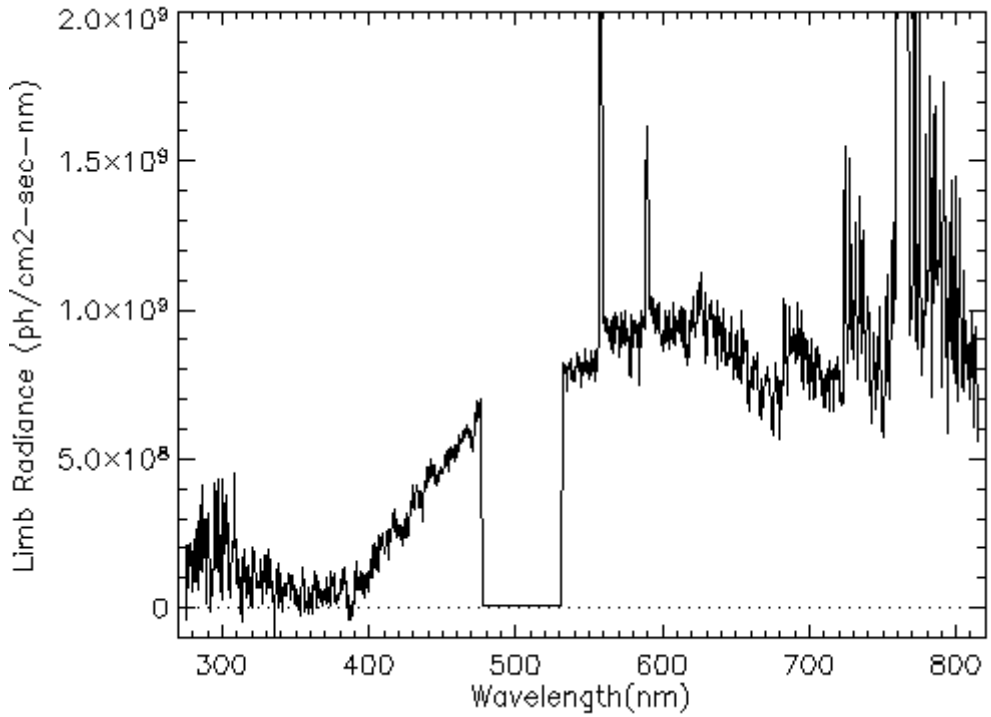
$H + O_3$

$H_2O + hv$

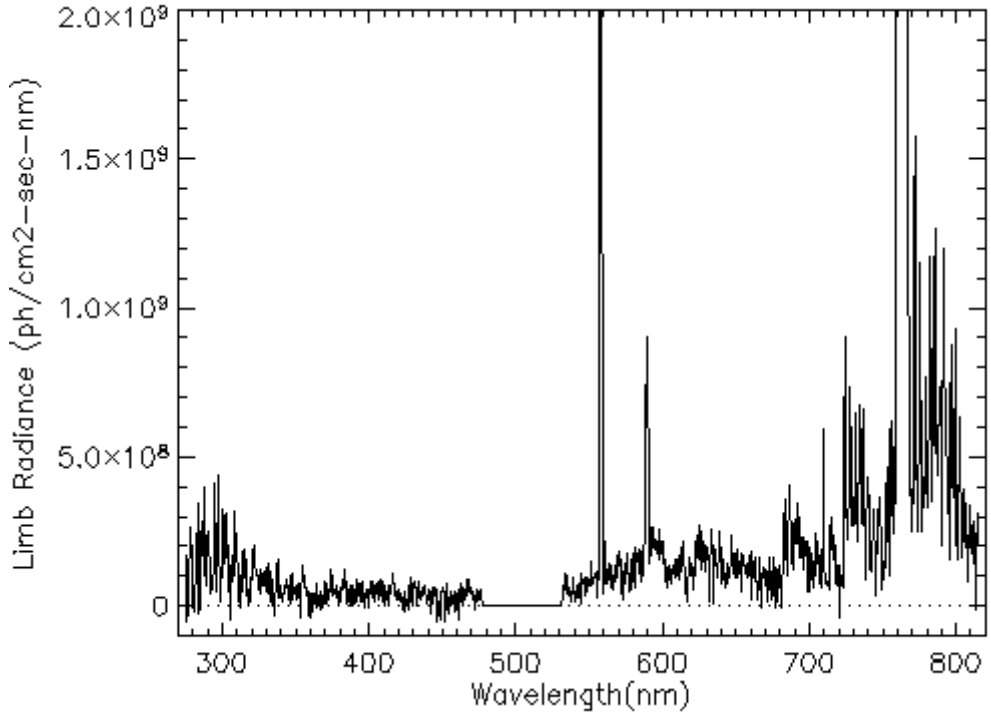
$O_3 + hv$

$NO + O$

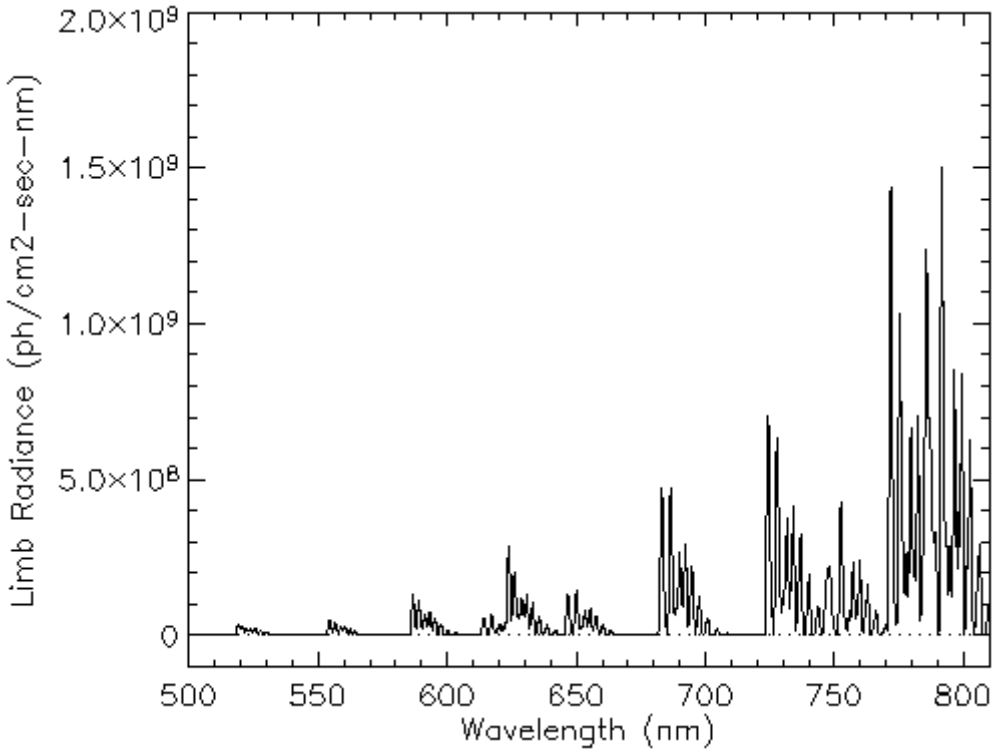
- Spectra can also yield temperature.
- The absorption of an emission can also yield information.
- The ratio of different emissions can also be used to provide on-orbit calibration.
- Multiple approaches can yield significant amounts of extra information.



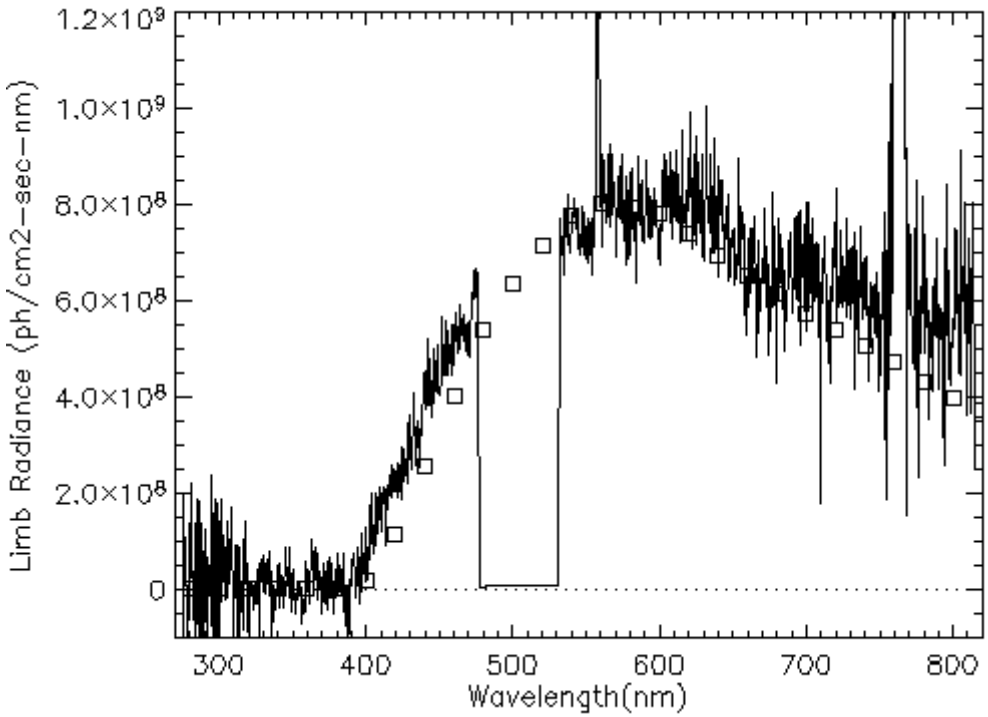
Averaged OSIRIS limb radiance spectrum for 18 May, 2003, Antarctic night conditions with bright continuum emission. The continuum beginning longwave of 400 nm is produced by the $NO+O \rightarrow NO_2+h\nu$ chemiluminescent reaction in the upper mesosphere and lower thermosphere. Other features include the OH Meinel vibration-rotation bands, the 762 nm $O_2(b^1\Sigma_g^+-X^3\Sigma_g^-)$ 0-0 band (offscale), the OI 558 nm emission (offscale), the Na doublet at 589 nm and the Herzberg bands in the 300 nm region.



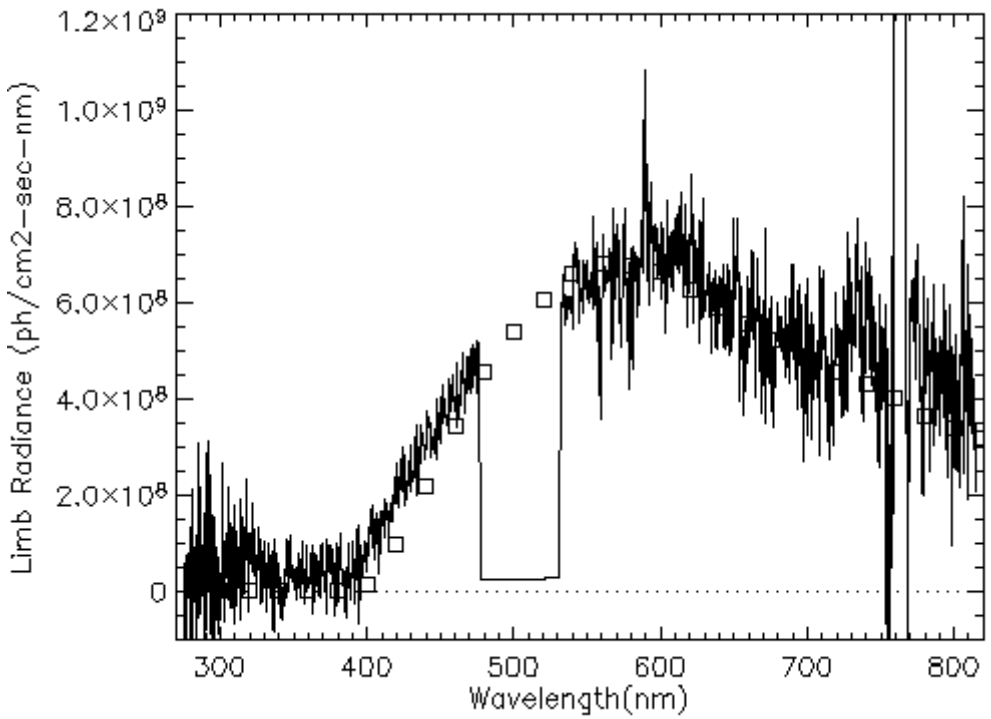
Averaged OSIRIS low latitude night airglow background spectrum for 18 May, 2003, latitude range approximately 20º South to 45º South; observations exclude the effects of auroral particle generation of the NO_2 continuum. The OH 690 nm 7-2, 730 nm 8-3, 775 nm 9-4 and 790 nm 5-1 bands are all clearly visible in the spectrum. The 762 nm $O_2(b^1\Sigma_g^+\text{-}X^3\Sigma_g^-)$ 0-0 band (offscale), the OI 558 nm emission (offscale), the 589 nm Na doublet and the Herzberg bands in the 300 nm region are also present.



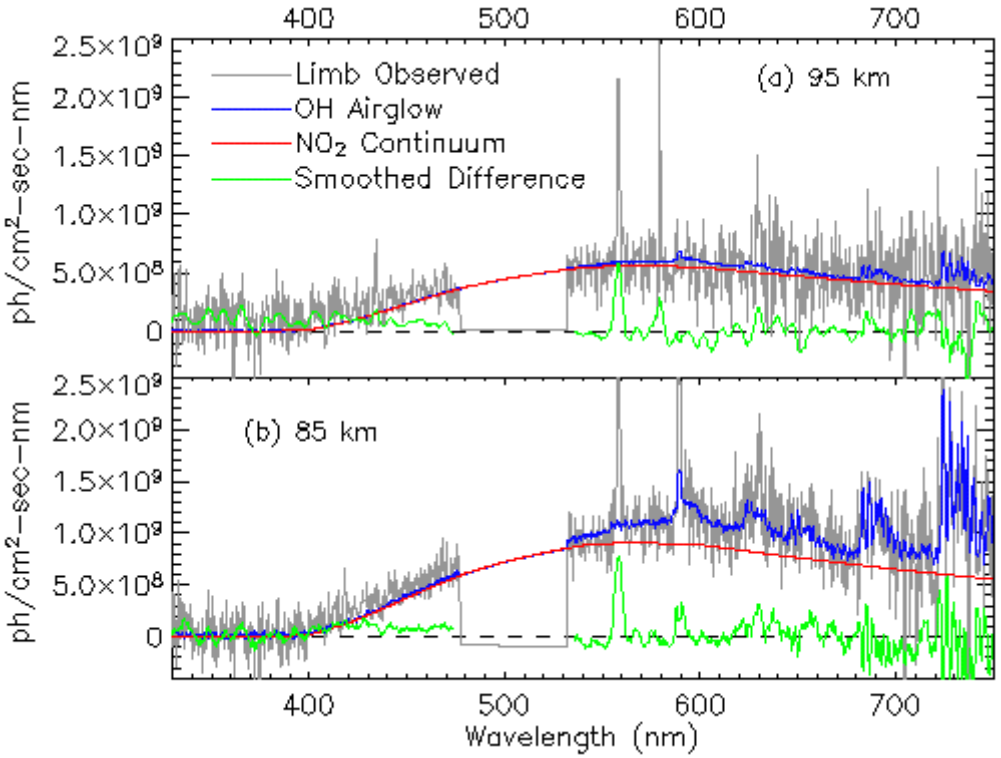
A scaled synthetic OH spectrum in the 500 to 810 nm region to identify the weak OH Meinel bands present in the observed night airglow background spectrum shown previously. The synthetic spectrum is convolved with the OSIRIS 1 nm slit width. Additional bands identifiable in the observed spectrum are 8-2 at 590 nm and 9-3 at 625 nm.



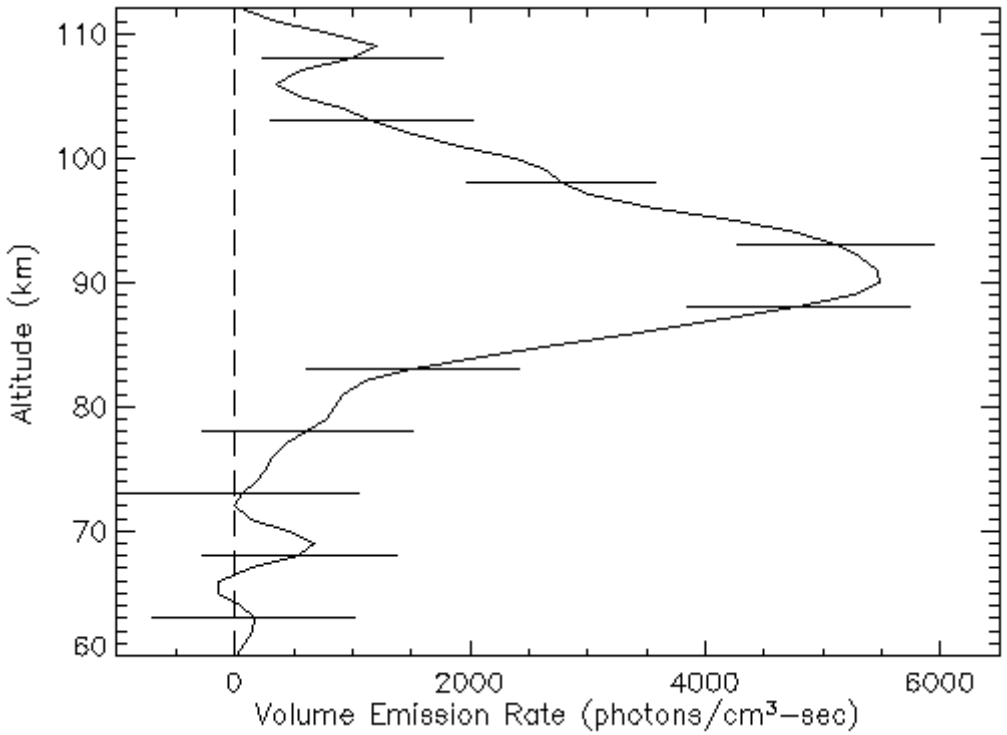
The difference of the two averaged OSIRIS limb radiance spectra for 18 May, 2003. (previous airglow spectra). The square symbols are the measured NO_2 continuum from the Becker *et al*. laboratory spectra for a pressure of 1 mTorr, scaled to the observed OSIRIS NO_2 continuum curve at 580 nm .



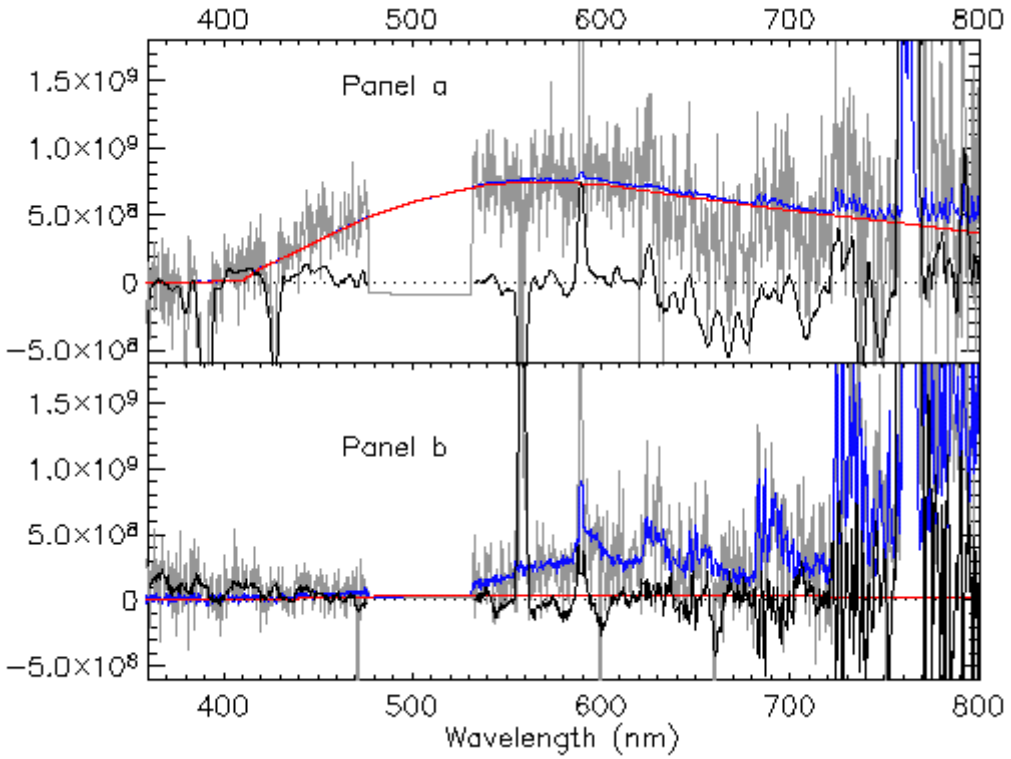
The same as previous slide but for 26 May, 2005. Again the square symbols are from the Becker *et al*. laboratory spectra for a pressure of 1 mTorr, scaled to the observed OSIRIS NO_2 continuum curve at 580 nm.



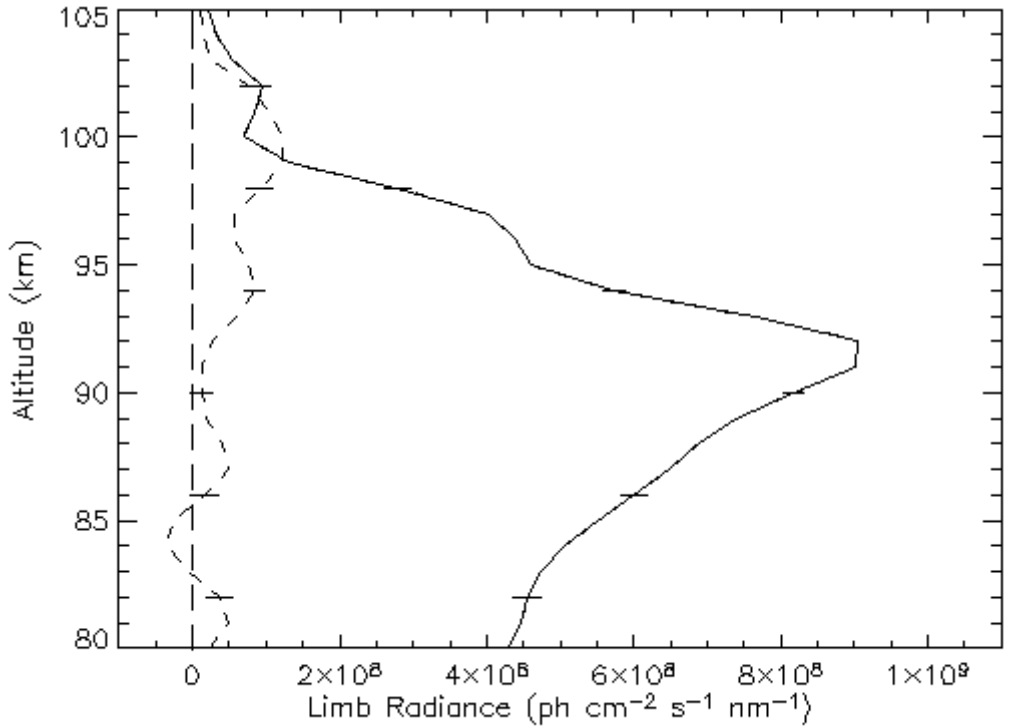
Examples of limb radiance spectra at two altitudes together with the combined least-squares fitting of the scaled low latitude OSIRIS background OH spectrum and scaled NO_2 continuum spectrum. The individual spectra are a subset of the limb scan spectra obtained on 26 May, 2005, 15:10 UT, latitude 82ºS, longitude 123ºE, solar zenith angle 119º, solar local time 23:25. The difference spectrum has been smoothed to improve clarity.



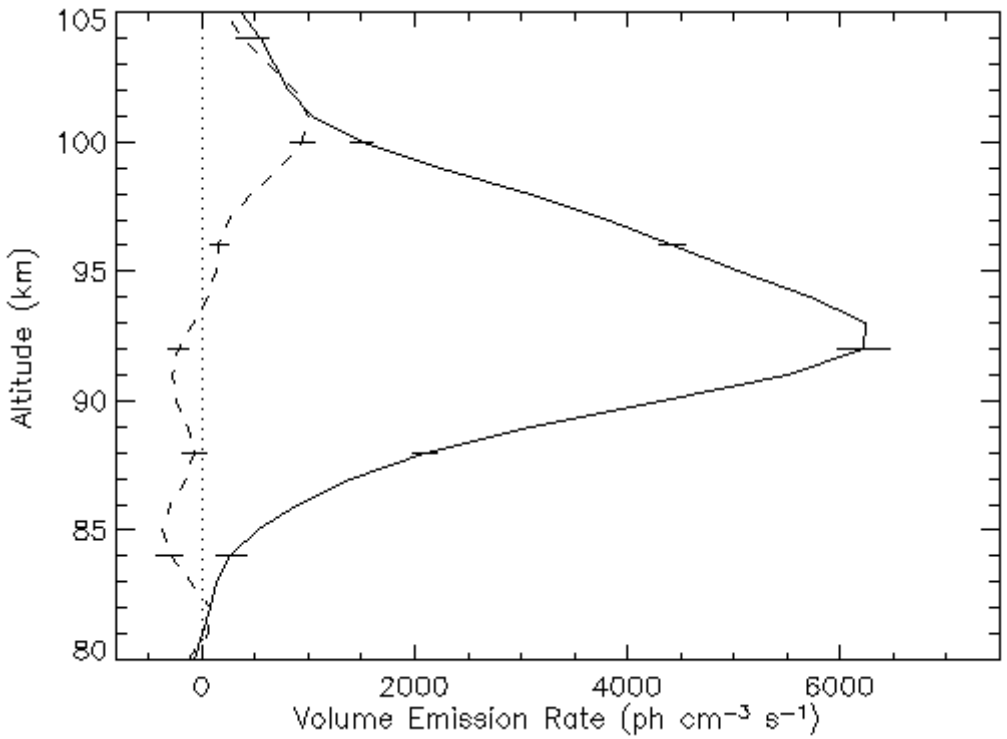
An NO_2 continuum volume emission rate altitude profile from a single OSIRIS limb scan, 26 May, 2005, 15:10 UT, latitude 82ºS, longitude 123ºE, solar zenith angle 119º, solar local time 23:25. The volume emission rate is based on the total NO_2 continuum from 400 to 1400nm assuming a spectral shape equivalent width of 450 nm. The volume emission rate errors at each altitude are derived from the noise-induced continuum uncertainty in the limb radiance measurements. The noise level is typical.



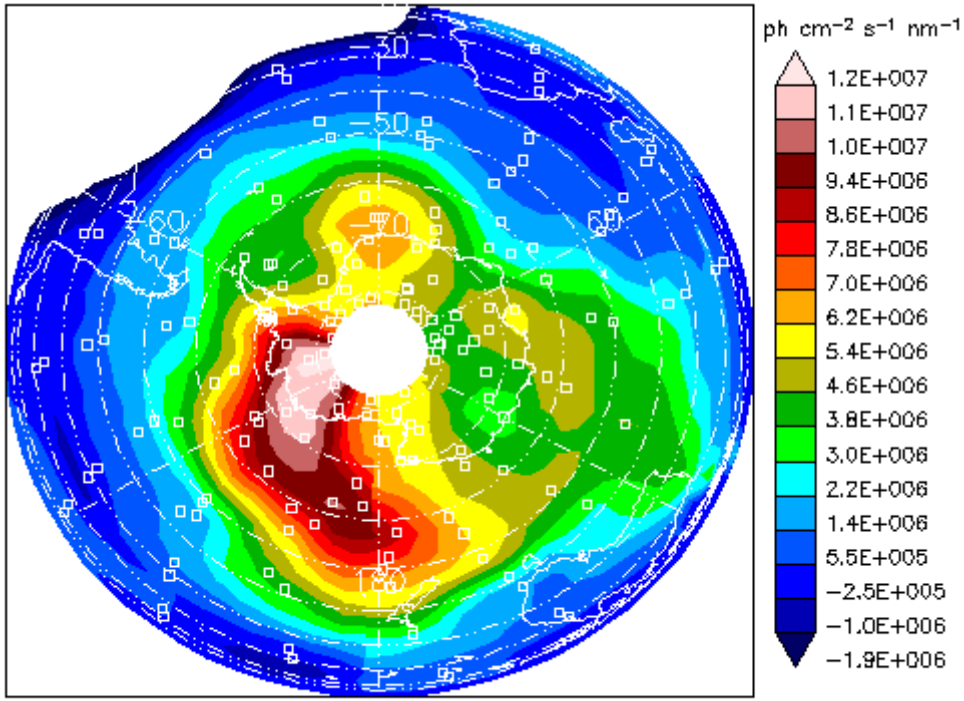
Limb radiance spectra observed by OSIRIS at 88 km tangent altitude, 9 May 2005. Panel a – From the dark polar region (75º south latitude, 225º east longitude) with enhanced NO_2 continuum radiance. Panel b – Mid-latitude (29º south latitude, 221º east longitude) with very little NO_2 continuum. Gray – Observed limb spectrum; Blue – Least squares fit of sum of scaled night airglow and scaled NO_2 continuum spectra; Black – Residual of gray minus blue components, smoothed to improve clarity; Red – Derived NO_2 continuum at 88 km limb.



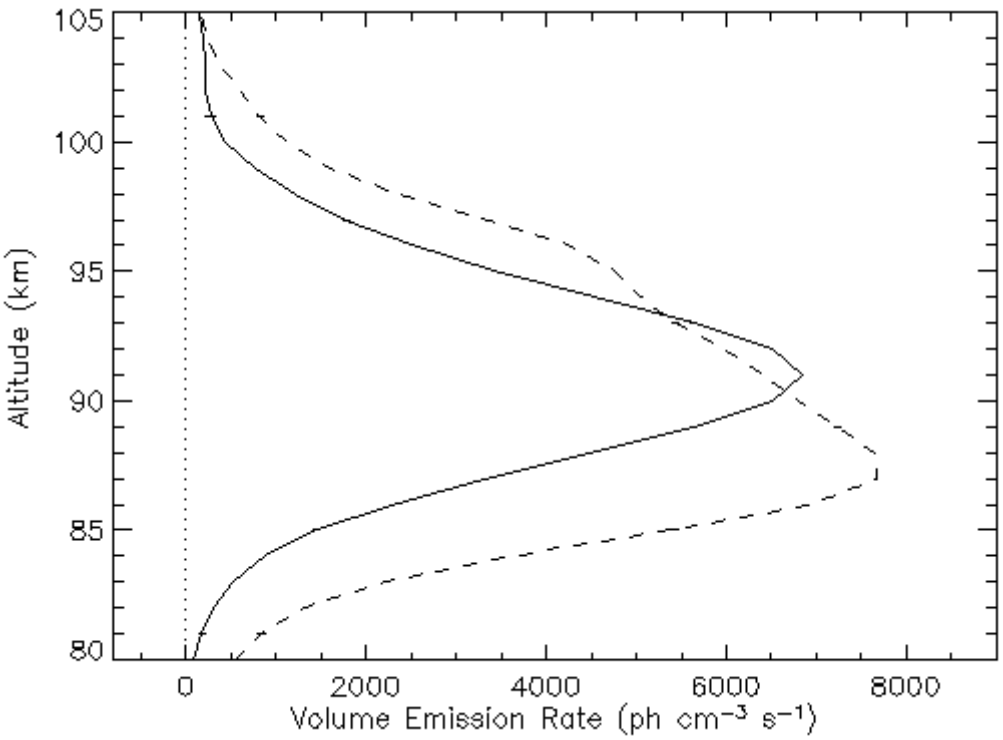
Limb radiance profiles of NO_2 continuum differential brightness at 580 nm, 9 May 2005, for the two cases in previous slide. Solid – 75º south latitude. Dashed – 29º south latitude.



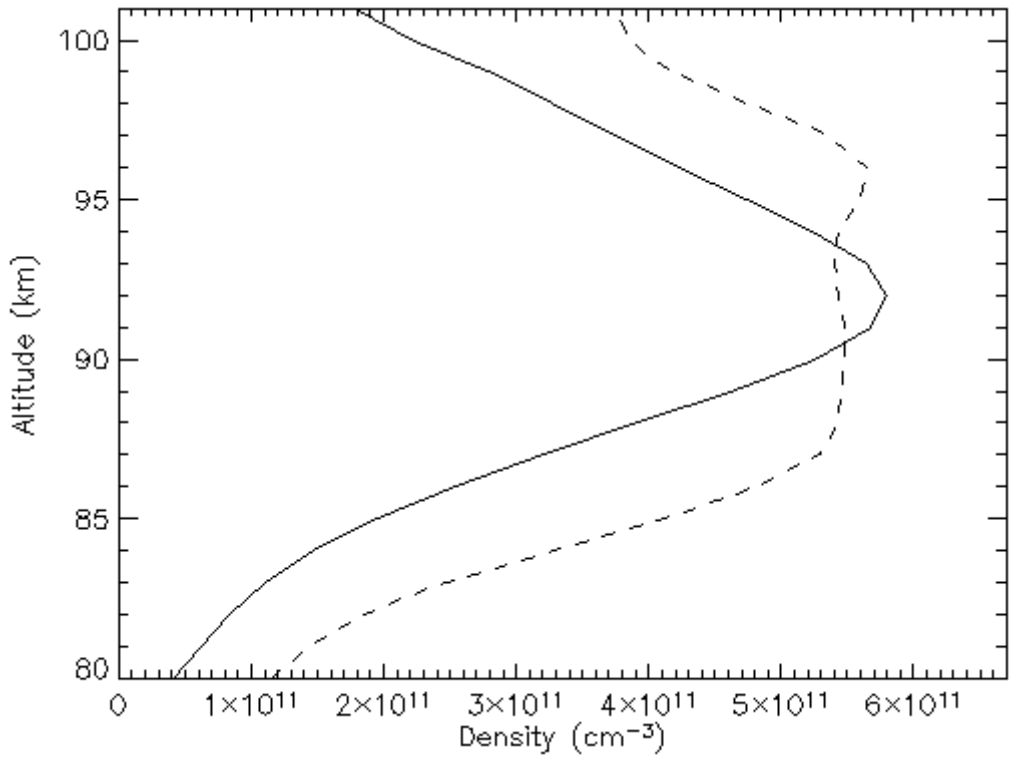
Volume emission rate profiles of total NO_2 continuum brightness, 8-9 May 2005, for the two limb scans shown previously. Solid – 75º south latitude. Dashed – 29º south latitude.



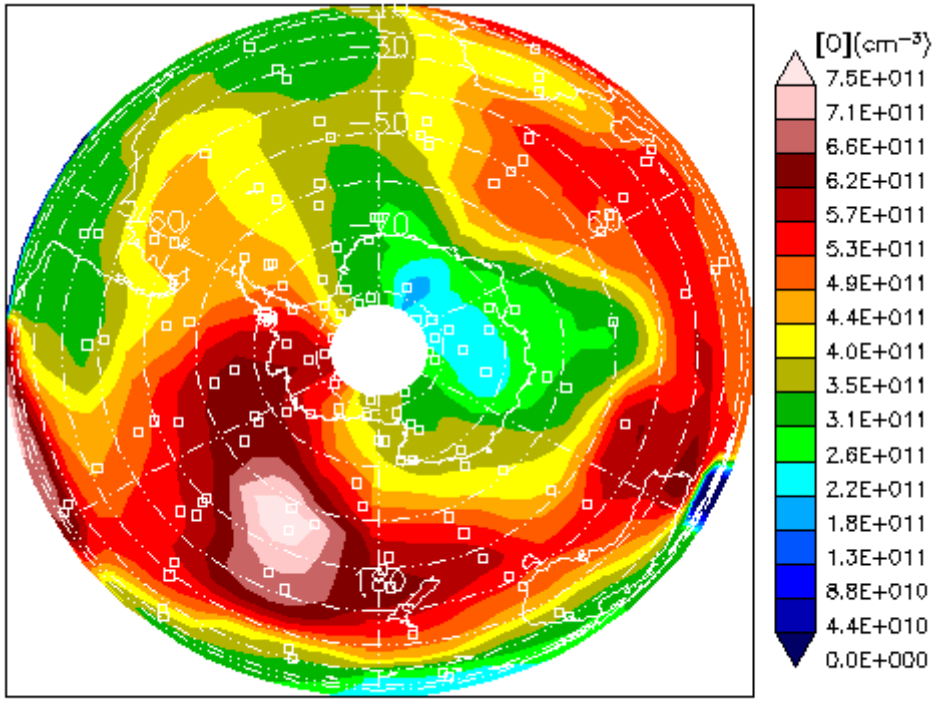
Southern Hemisphere map of NO_2 continuum differential brightness for 8-9 May 2005 as observed by OSIRIS. The units are referred to zenith observations at 580 nm. The white squares mark the locations of OSIRIS limb profile measurements. Data in the South Atlantic Anomaly region are omitted due to excessive detector noise.



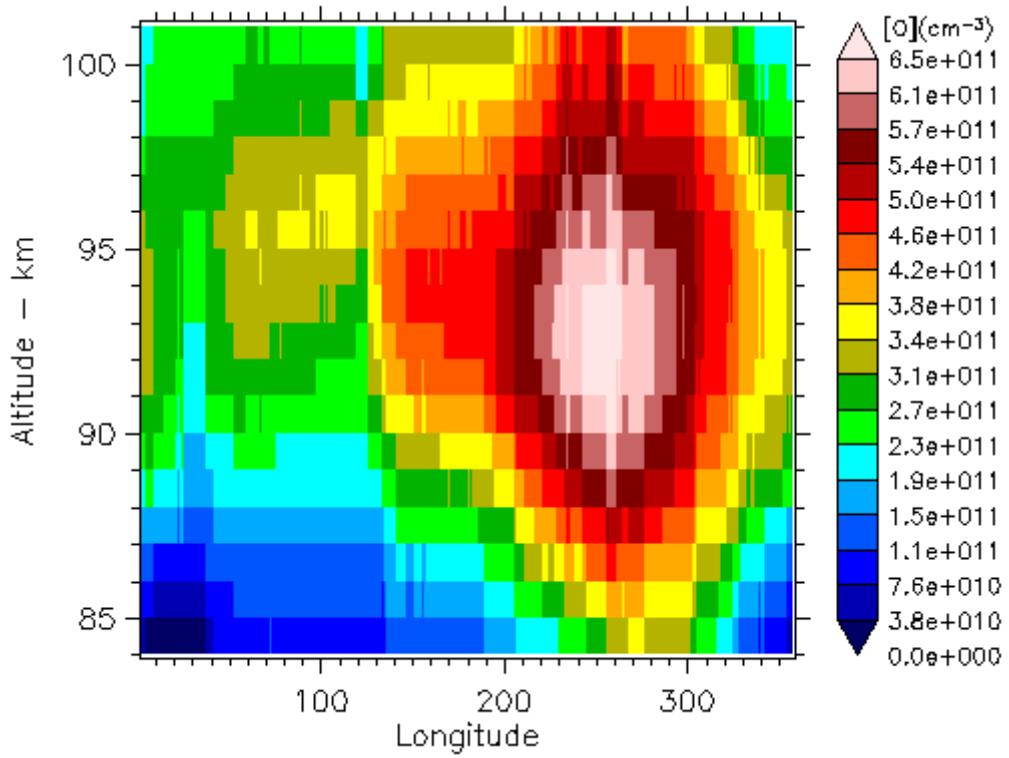
Volume emission rate profiles of the 762 nm $O_2(b^1\Sigma_g^+\text{-}X^3\Sigma_g^-)$ 0-0 band, 9 May 2005, for the two limb scans referred to previously. Solid – 75º south latitude. Dashed – 29º south latitude.



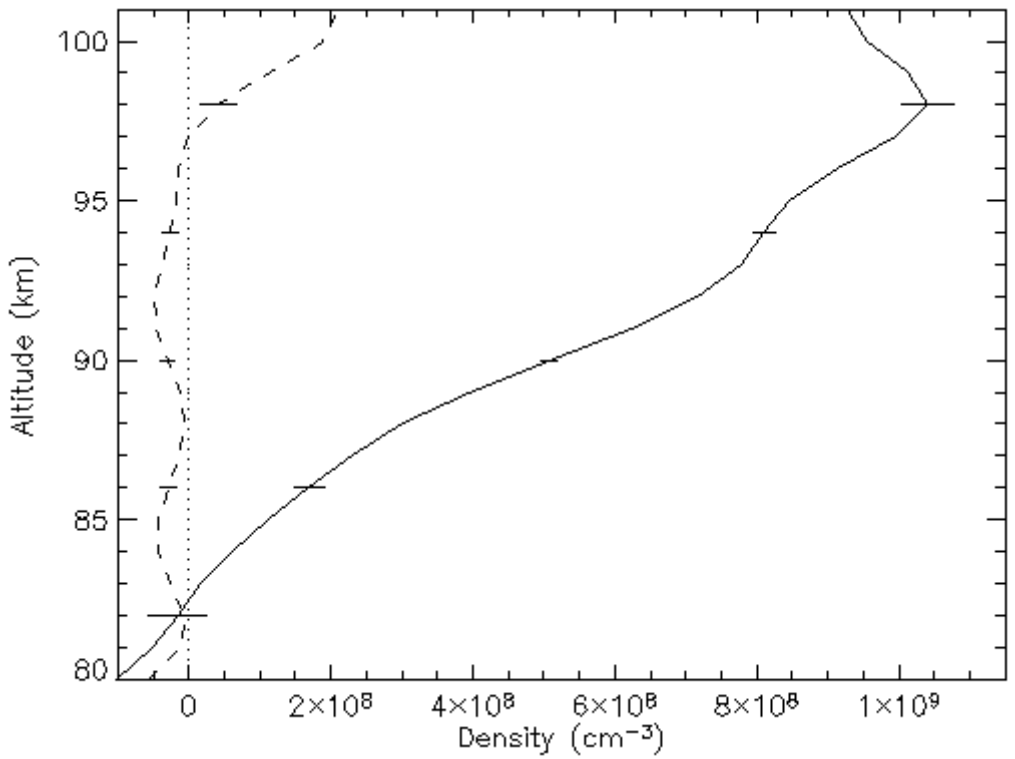
Atomic oxygen density profiles derived from the $O_2(b^1\Sigma_g^+\text{-}X^3\Sigma_g^-)$ 0-0 band VER profiles on 9 May 2005, for two limb scans.
Solid – 75º south latitude. Dashed – 29º south latitude. The measurement uncertainty is approximately $2\text{x}10^{10}$ cm^{-3} over the altitude range.



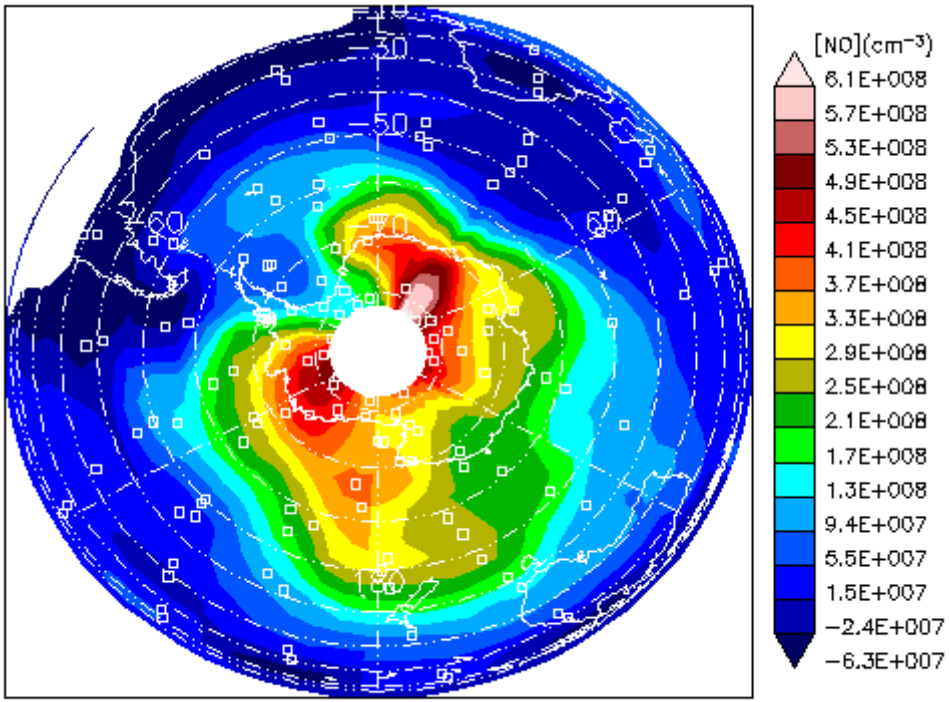
Southern Hemisphere polar projection of the derived atomic oxygen density at 90 km altitude, for 8-9 May 2005.



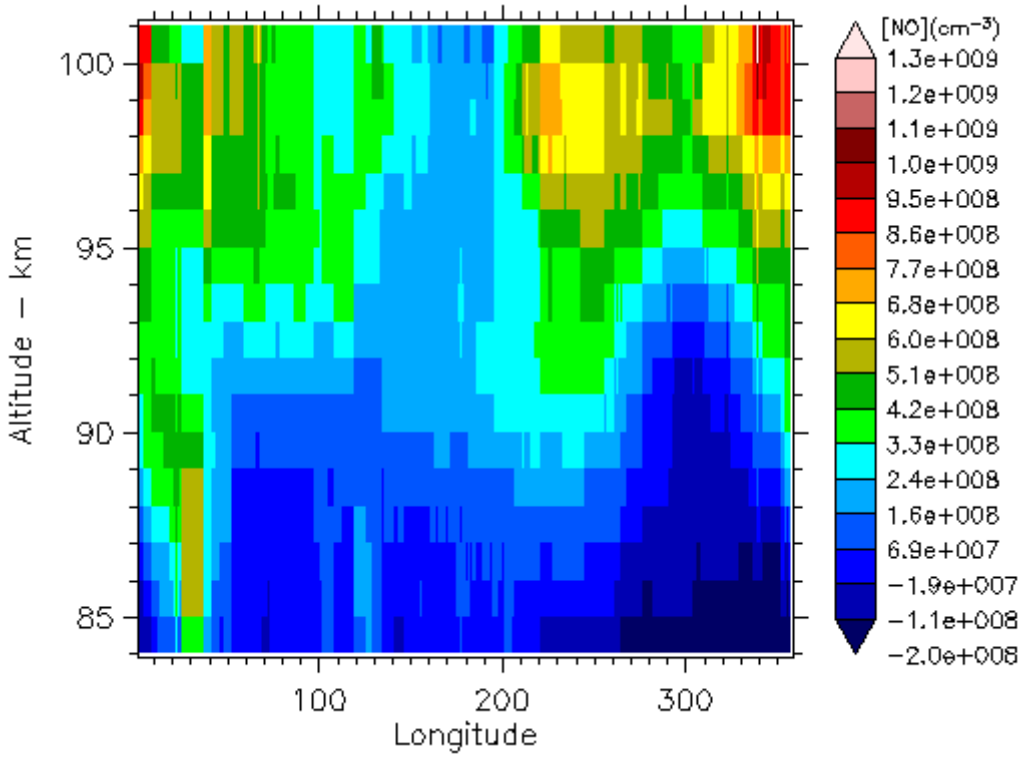
Atomic oxygen density profile versus longitude for 8-9 May, 2005. Limb scans between 70º South latitude and 80º south latitude are included.
Densities are derived from the OSIRIS $O_2(b^1\Sigma_g^+\text{-}X^3\Sigma_g^-)$ 0-0 band observations.



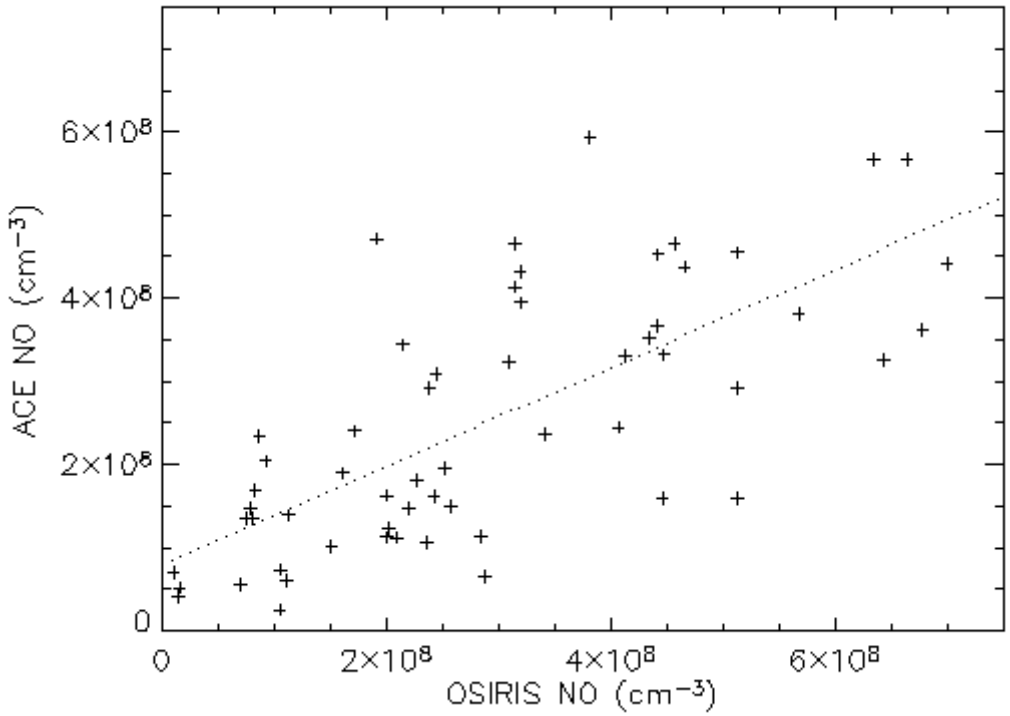
NO density profiles for 9 May 2005, for two limb scans. Solid – 75º south latitude. Dashed – 29º south latitude. The profiles are derived using the NO_2 VER profiles and the [O] profiles obtained from the 762 nm emission.



Southern Hemisphere polar projection of the derived NO density at 90 km altitude, for 8-9 May 2005.

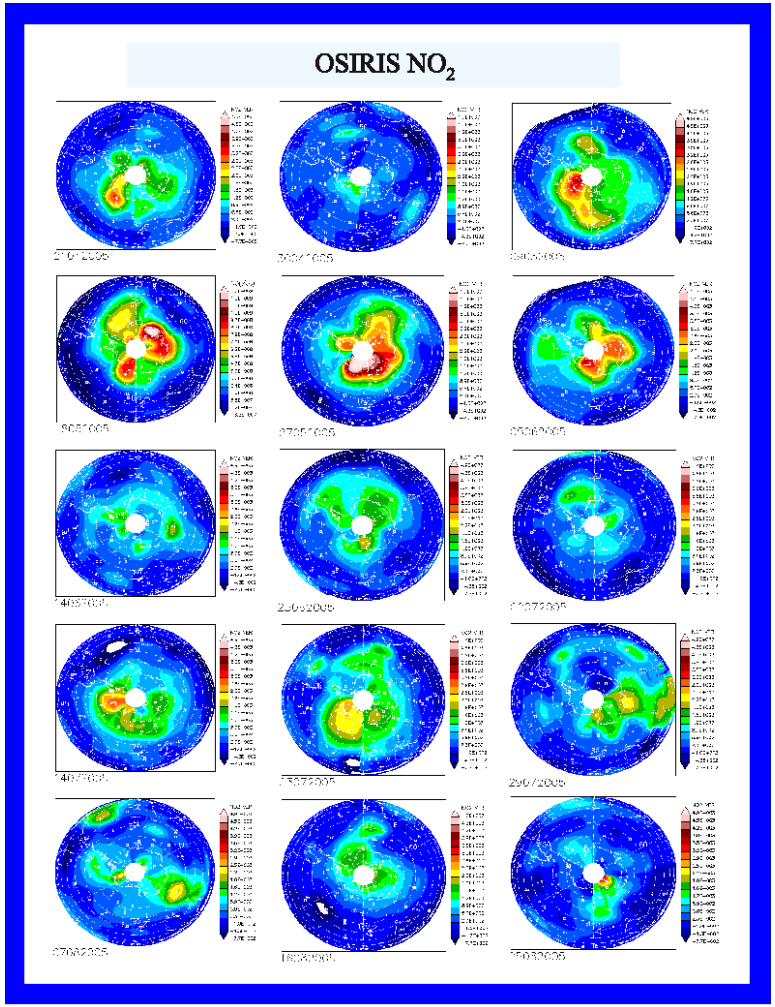


Derived NO vertical density profile versus longitude from OSIRIS observations centered at 75º south latitude for 8-9 May, 2005.

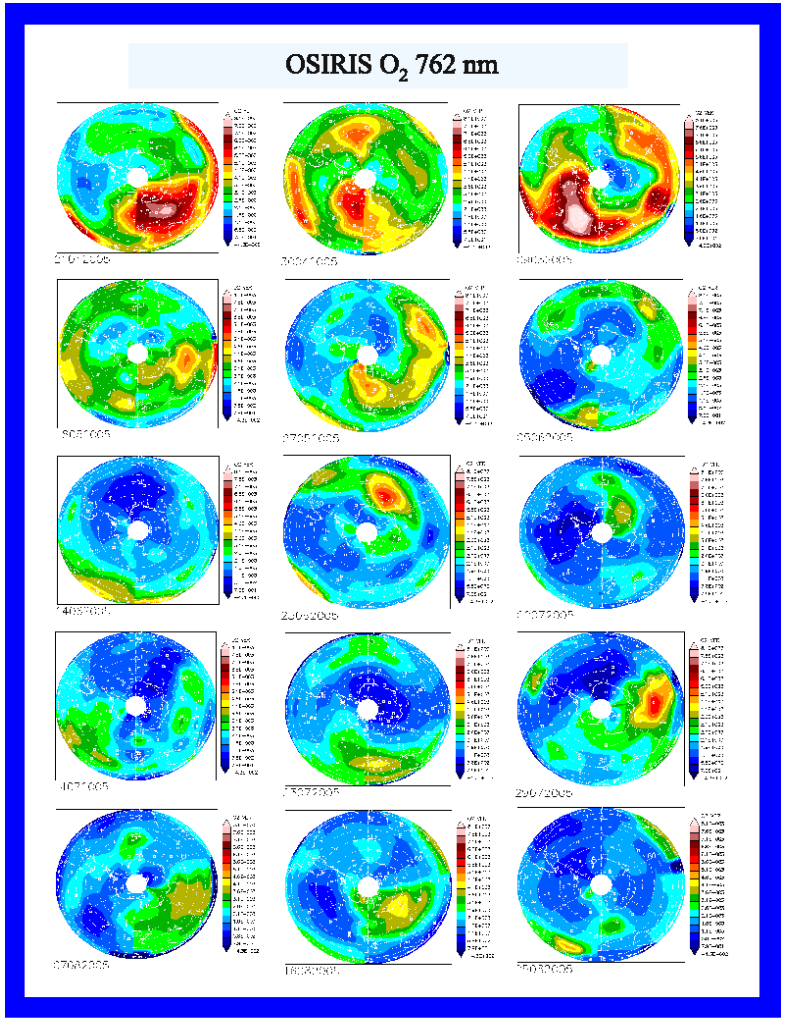


ACE-FTS average NO density from 85 to 100 km versus NO average density from 85 to 100 km derived from OSIRIS NO_2 continuum and [O] observations. Data are for Antarctic winter observations from 2004 to 2007.

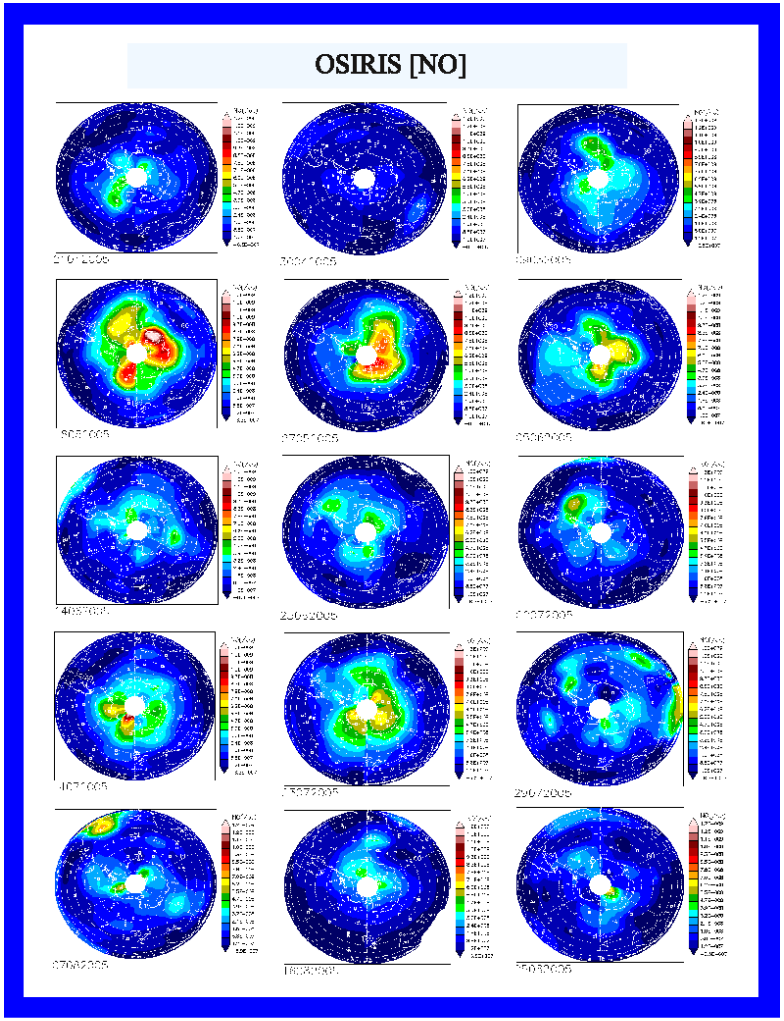
SH distribution of NO_2 emission at 90 km measured with OSIRIS.



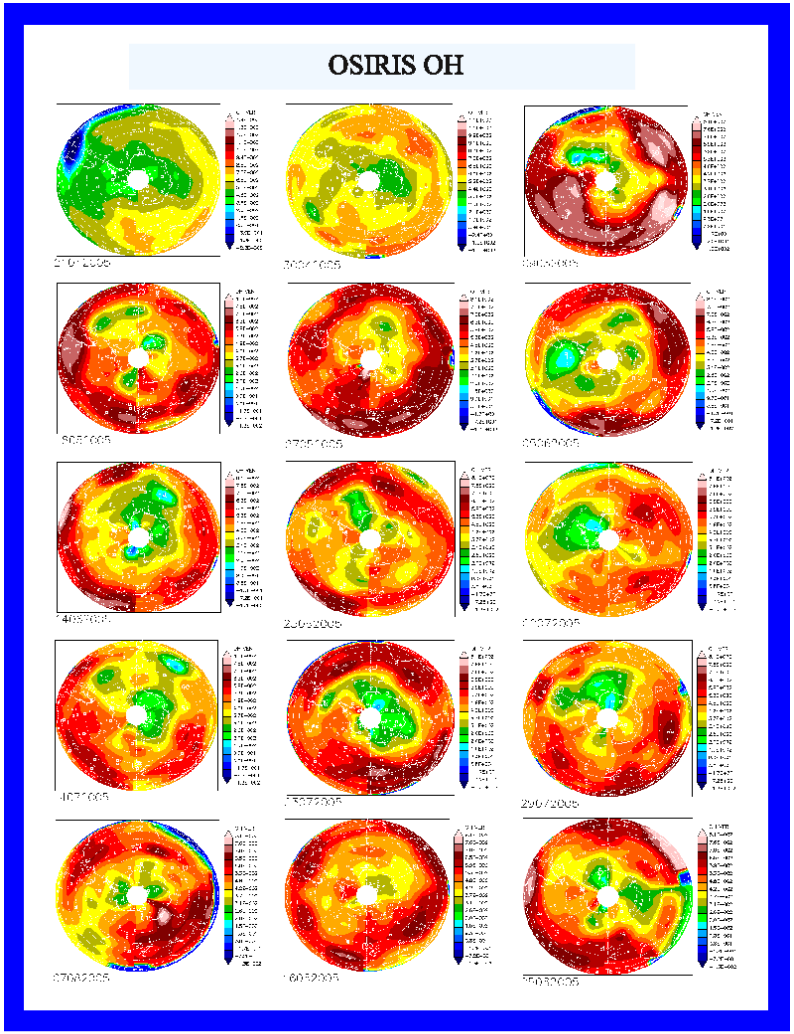
SH distribution of O_2 A-band at 90 km measured with OSIRIS.



SH distribution of NO
at 90 km derived from the
OSIRIS measurements
Shown previously.



SH distribution of OH
(8-3) Meinel Band
at 90 km measured with
OSIRIS.



Thank you for listening and please recognize that the problems you can study with OSIRIS are only limited by your imagination.

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