Mesospheric Ozone from the Hartley Band

Towards a complete OSIRIS ozone product in the middle atmosphere

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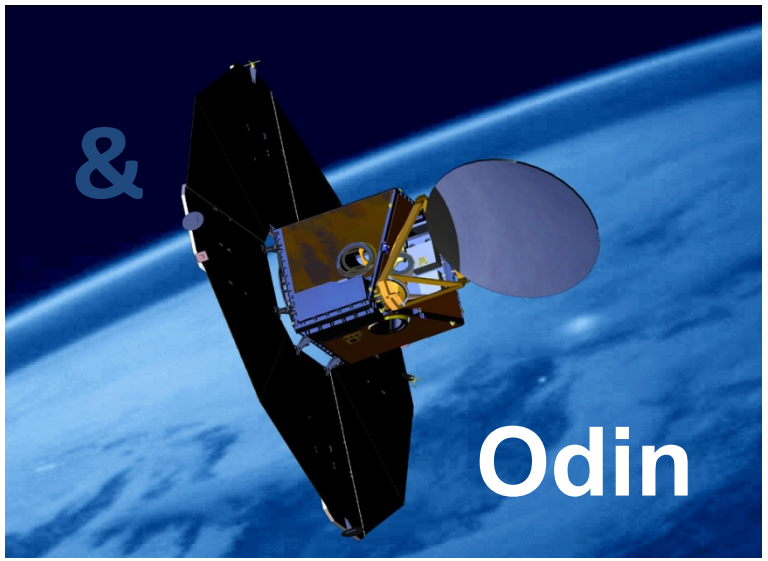
Stockholm University

YORK UNIVERSITÉ UNIVERSITY

UNIVERSITY OF SASKATCHEWAN

Outline

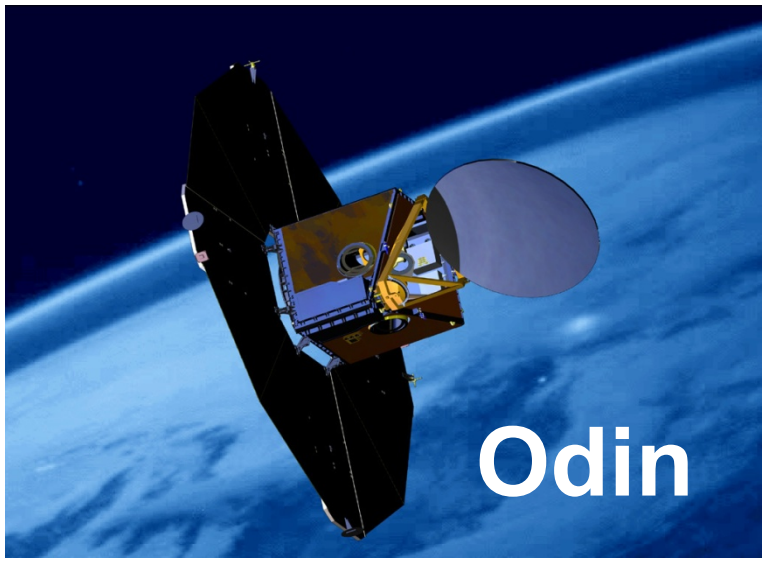
- Motivation
- Retrieval technique
- First results
- Conclusion
  outlook

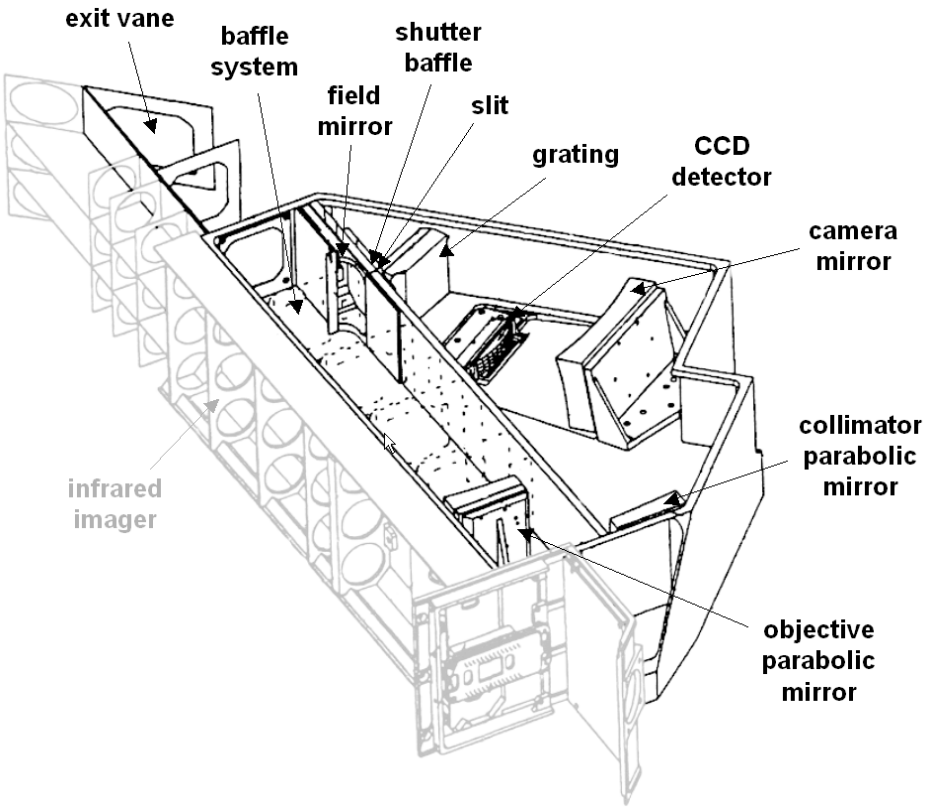


Odin basics…

- **Sweden, Canada, Finland & France**
- **2 instruments:**
  - Sub-mm / mm Radiometer (SMR)
  - Optical Spectrograph and InfraRed Imager System (OSIRIS)
- Space-pointing or Limb-scanning accuracy < 1 arcmin (reconstructed)
- **Launched on February 20, 2001**
- Designed lifetime: 2 years
- Upcoming anniversary: 9 years…

- Small satellite, 250 kg
- Operated by Swedish Space Corporation
- Sun-synchronous near-polar orbit at ~600 km altitude, inclination 97.8°





OSIRIS

Optical Spectrograph and InfraRed Imager System

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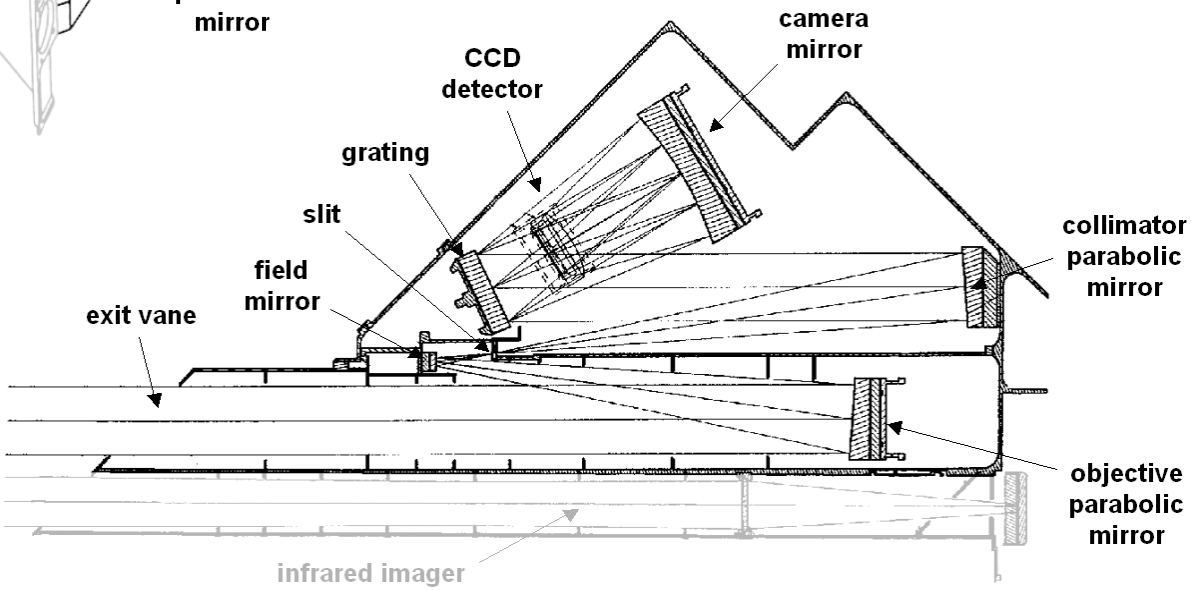
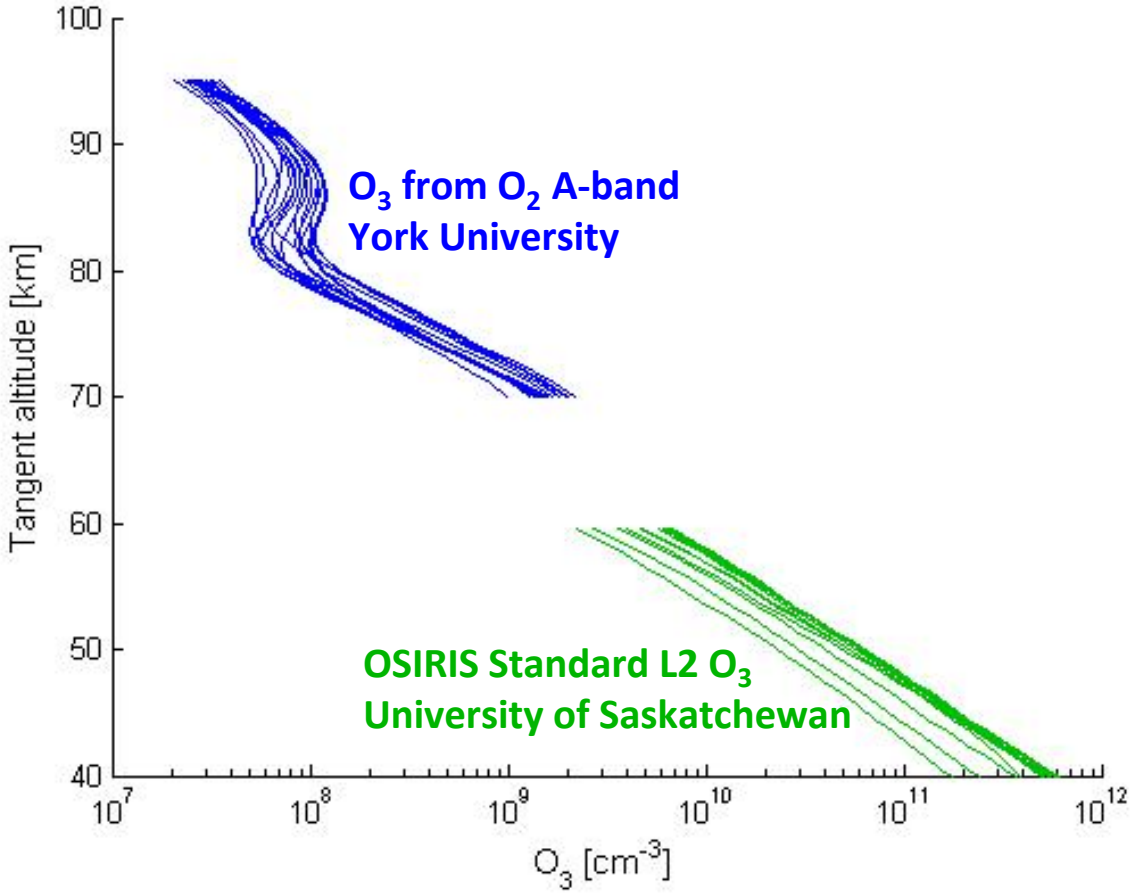


OSIRIS O_3 profiles for September 2008

(zonally averaged, 80°S to 80°N, 10° steps)



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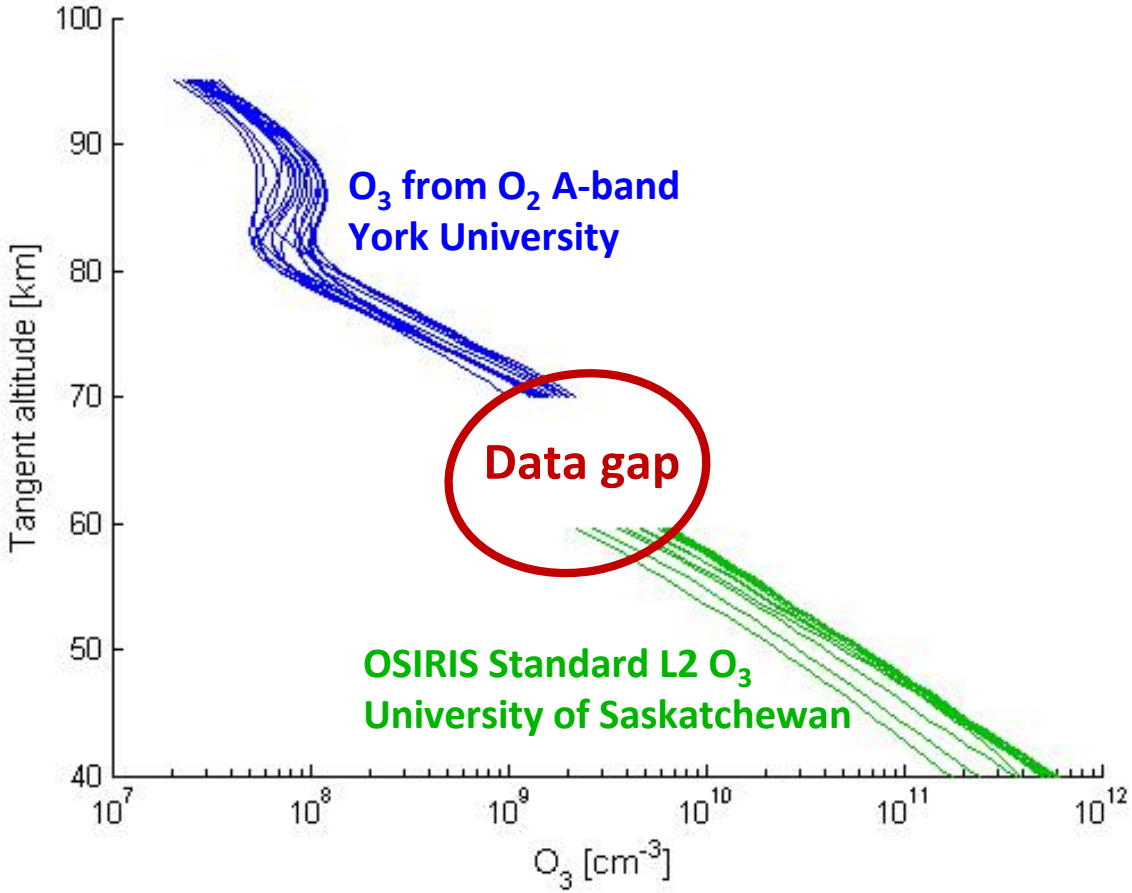


Earlier measurements in the mesosphere using the Hartley Band

- **UV Spectrometer on the Solar Mesosphere Explorer**

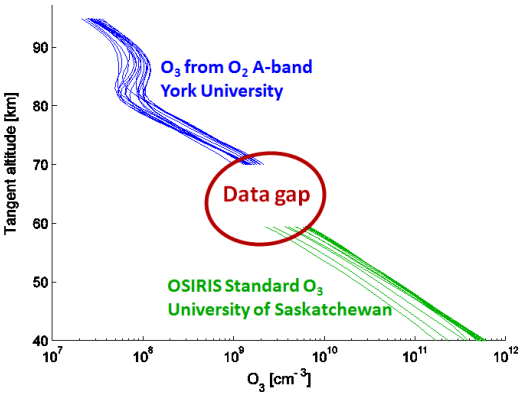
  O_3 concentrations between 48 and 70 km from limb radiance profile measurements at 265 and 296 nm (Rusch et al., 1984)

- **SCIAMACHY on Envisat**

  O_3 concentrations between 35 and 65 km from limb radiance spectra measurements between 250 and 310 nm (Rohen et al., 2006; Savigny et al., this workshop)

Pushing the retrieval to high altitudes

(⟶ overlap with A-Band retrieval ≥ 70 km)



Pushing the retrieval to **high altitudes**

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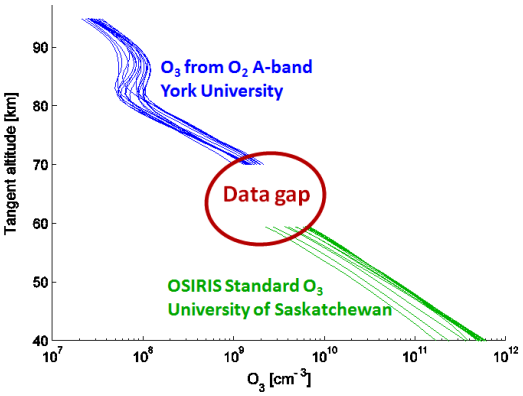

two challenges:

- **signal-to-noise ratio**

- **variability of total density profile**

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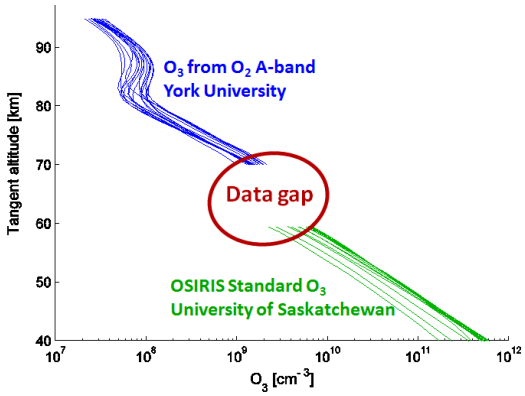

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- **signal-to-noise ratio**

  idea: use as many wavelengths as possible in the retrieval

  OSIRIS: 15 wavelength pixels at 276-289 nm that are not contaminated by airglow or auroral emissions

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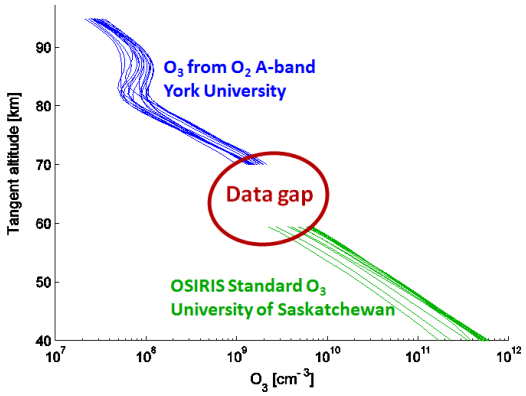

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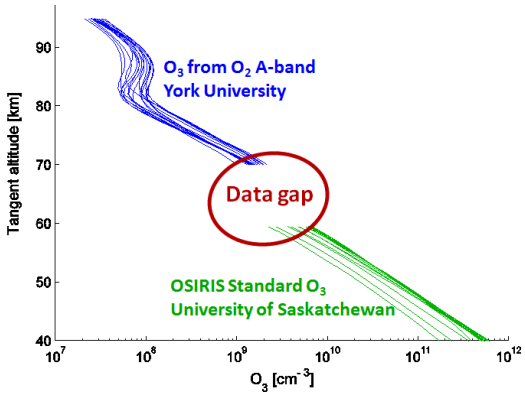

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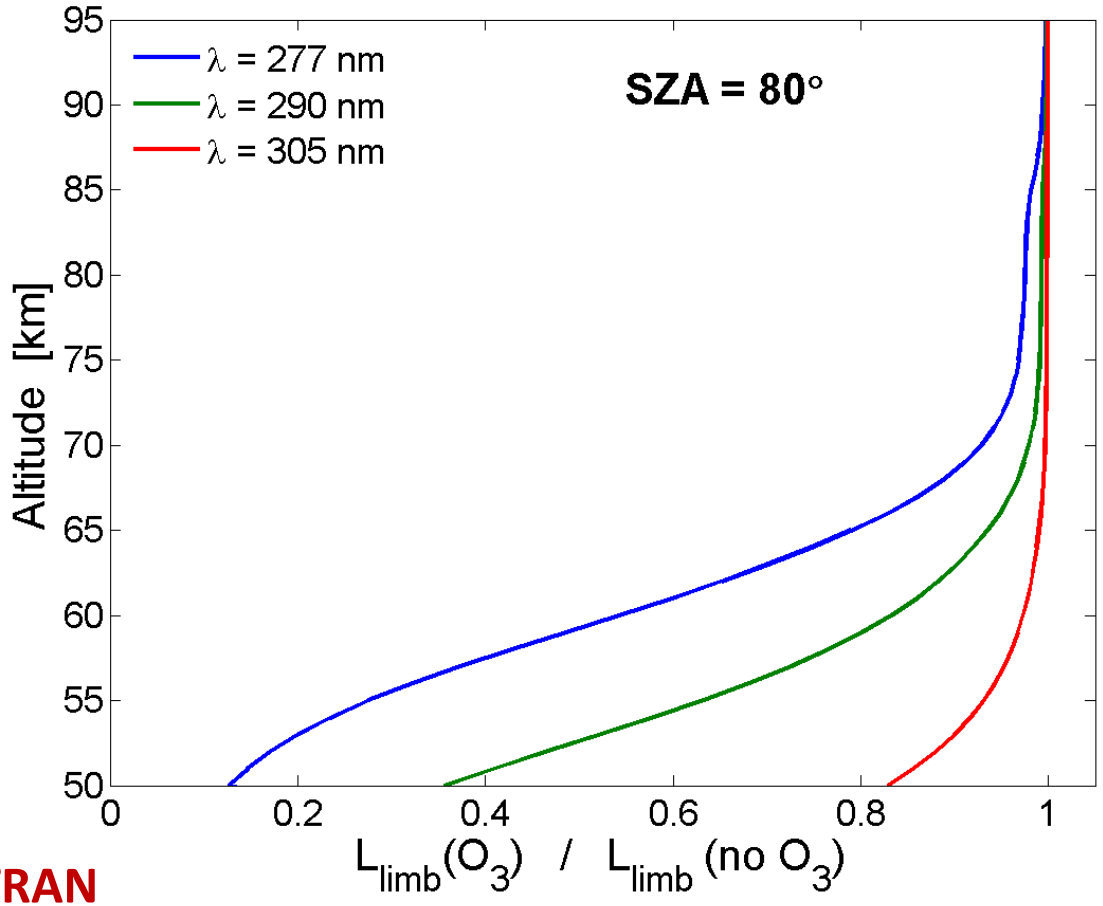
  idea: rather than radiances use radiance ratio between short and long UV wavelengths → largely independent of n_{tot} above the ”knee”

Effect of ozone absorption on limb scattering in UV



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ozone profile: Brasseur & Solomon

total density profile: MSIS, October, 50°N

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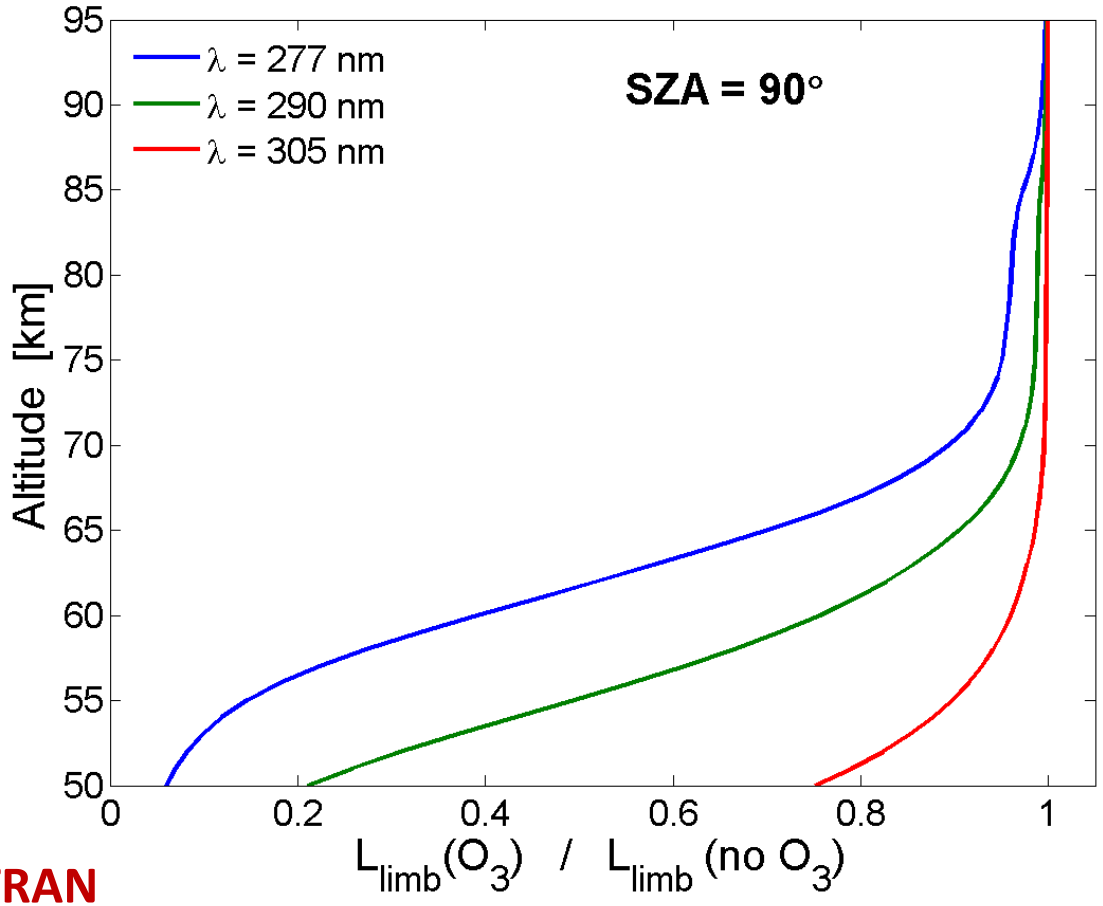

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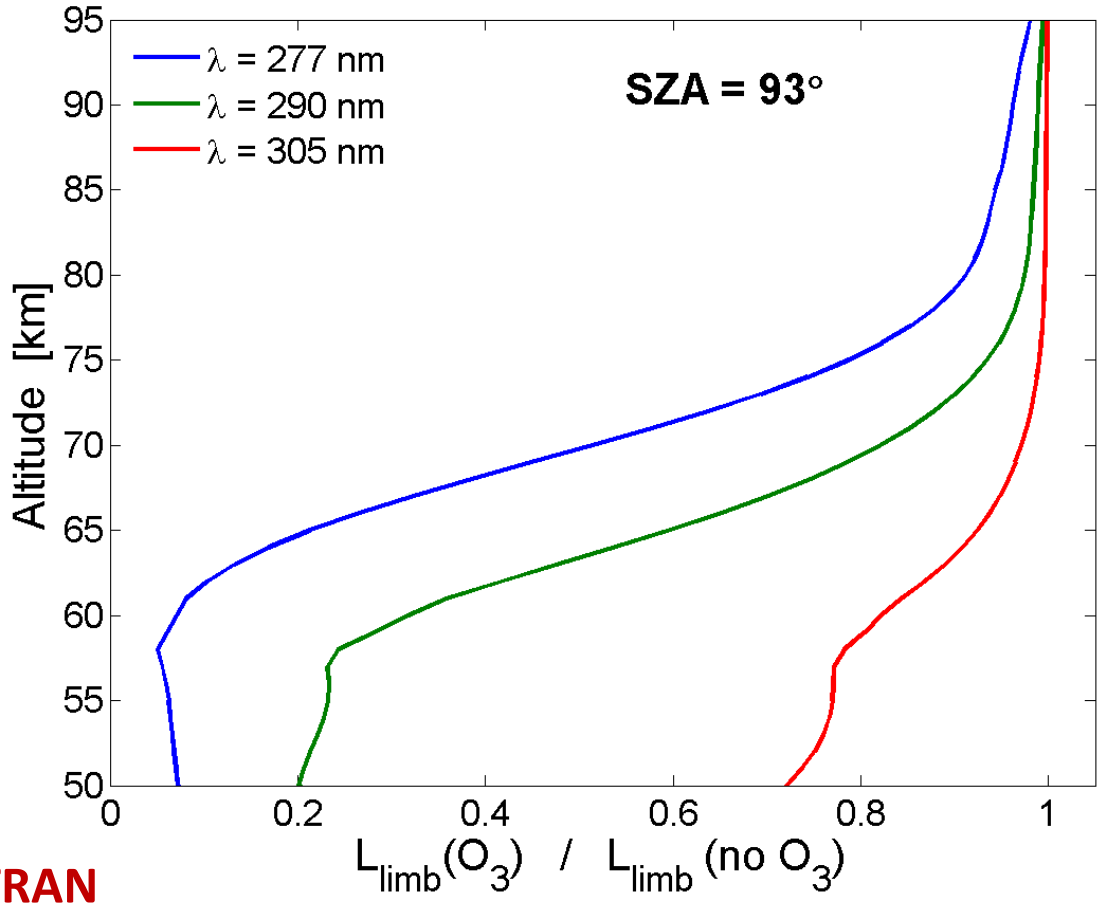

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Maximize information available from the UV limb data:

Do not treat the measurements at the individual wavelengths independently,
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→ solar spectrum,

reference spectrum from high altitudes with small ozone absorption

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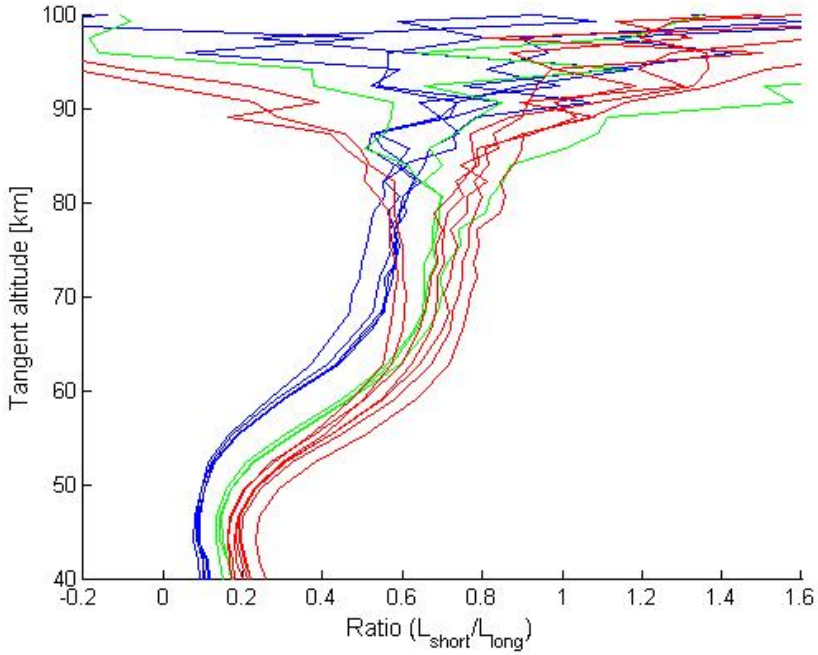
but include k[illegible]e spectral relati[illegible]m.
– [illegible]trum,
[illegible]erence spectrum from high altitudes with small ozone absorption

MISTAKE

- high sensitivity to limited signal-to-noise ratio at high altitudes
- high sensitivity to uncertainties in spectral calibration in the UV

Better:

- Base retrieval solely on *relative* altitude variation of individual limb profiles
- Let OEM take care of weighting together information from the individual wavelength pixels.



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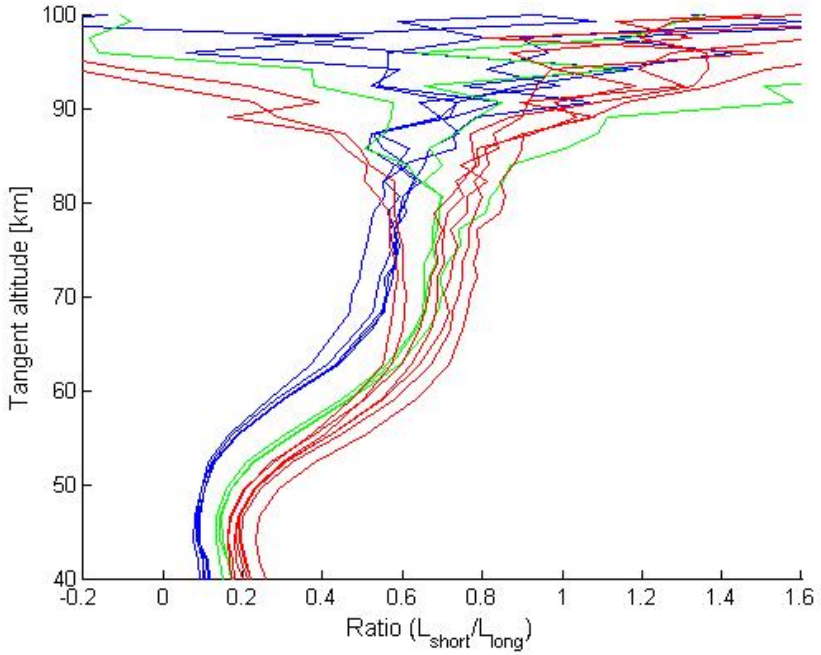
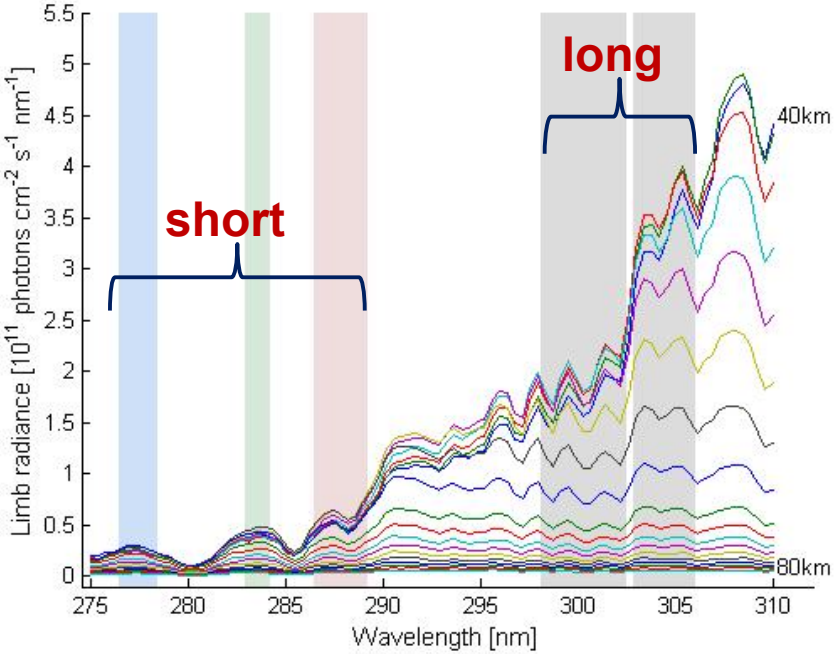
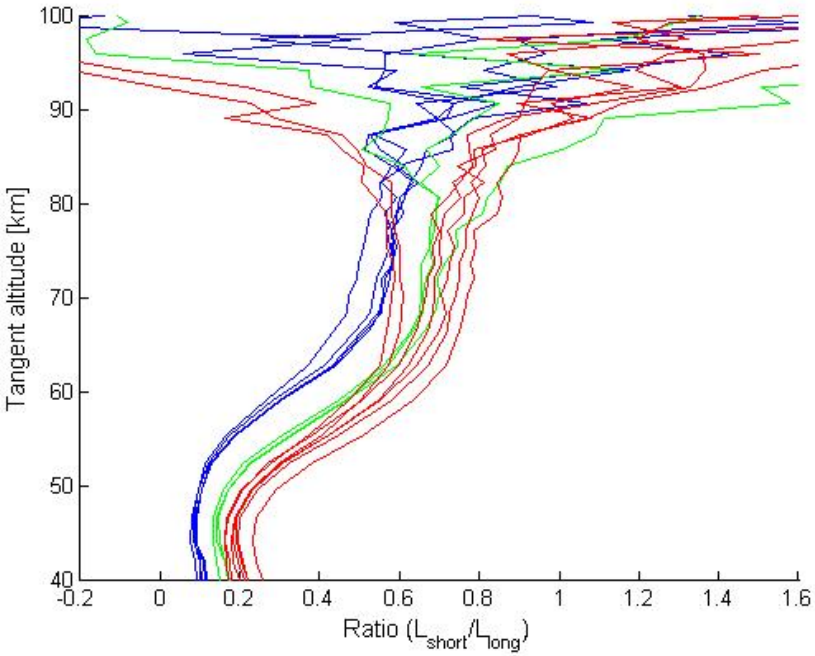
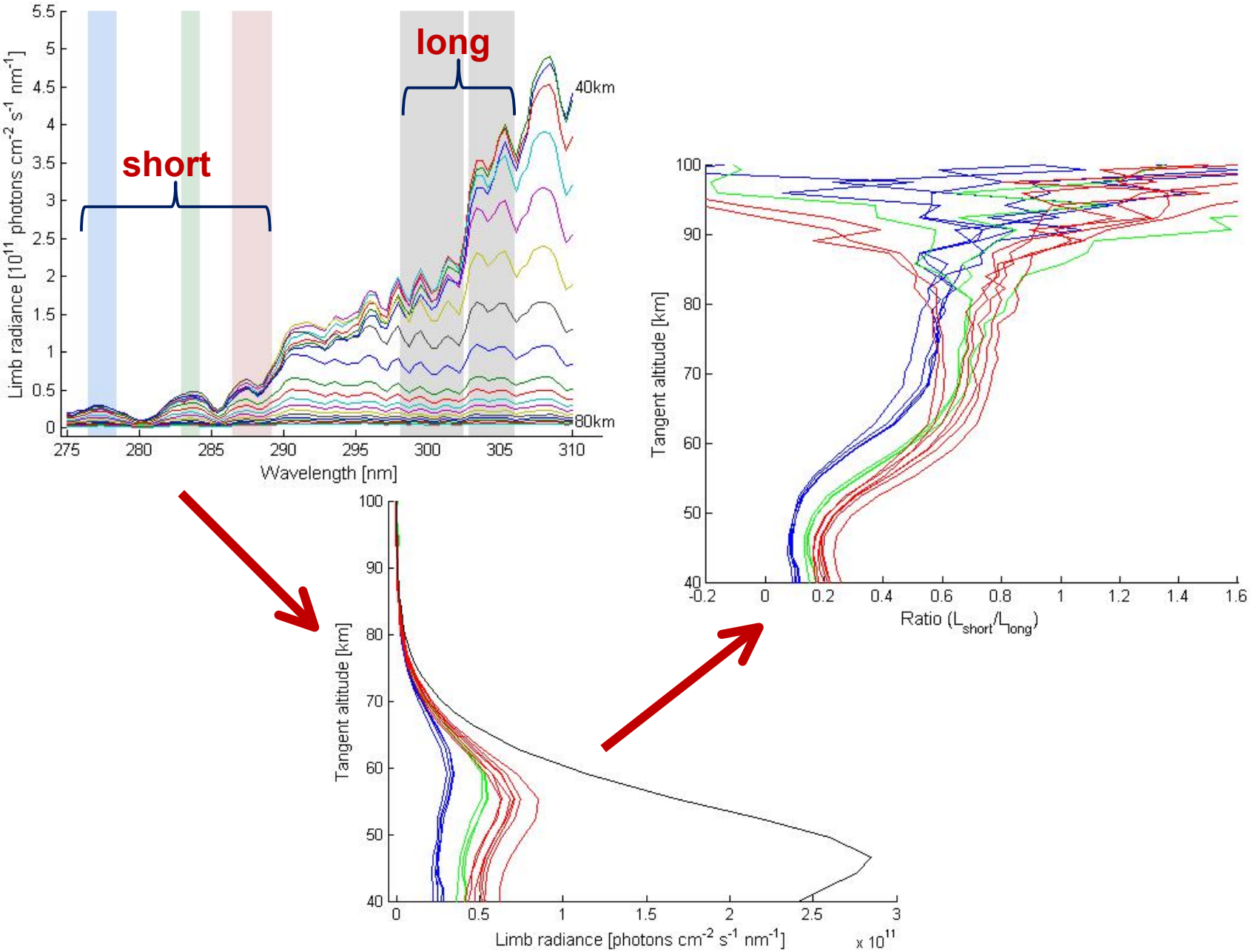


→ **upcoming retrievals**


short
long
40km
80km
Limb radiance [10^11 photons cm^-2 s^-1 nm^-1]
Wavelength [nm]
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
275
280
285
290
295
300
305
310


Tangent altitude [km]
Ratio (L_short/L_long)
100
90
80
70
60
50
40
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6


short
long
40km
80km
Limb radiance [10^11 photons cm^-2 s^-1 nm^-1]
Wavelength [nm]
Tangent altitude [km]
Ratio (L_short/L_long)
Limb radiance [photons cm^-2 s^-1 nm^-1]
x 10^11

Retrieval:

- Optimal estimation
- Forward model: fast single scattering code, validated with Sasktran
- Moderately nonlinear retrieval problem: Gauss-Newton iteration

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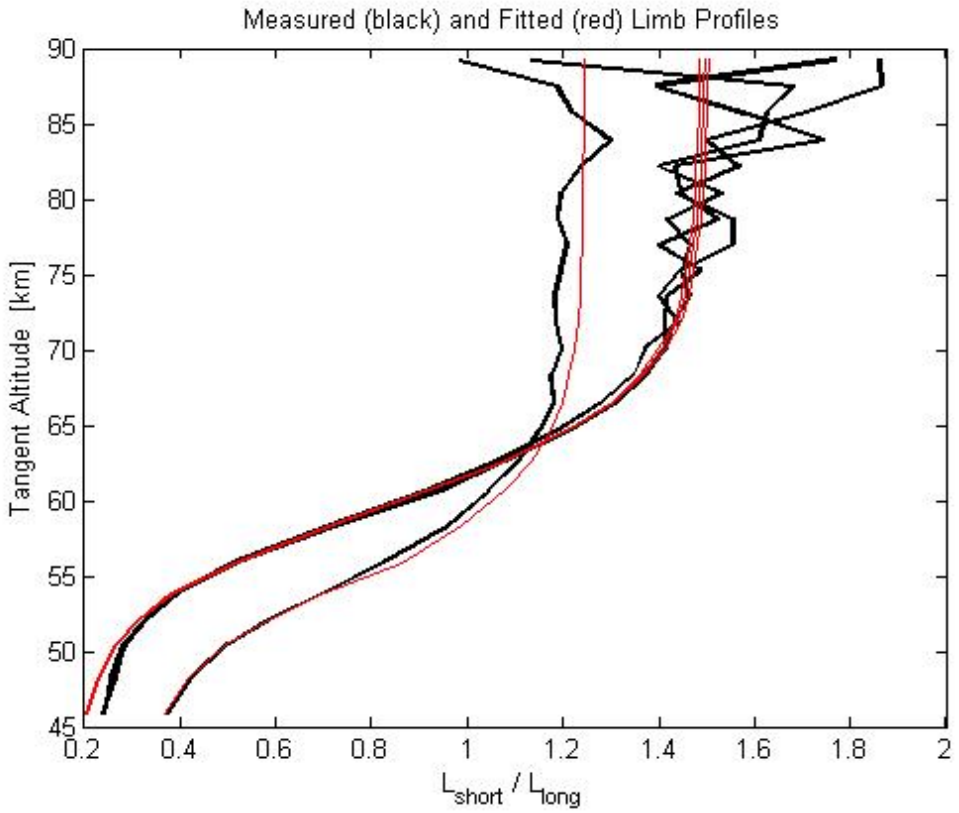

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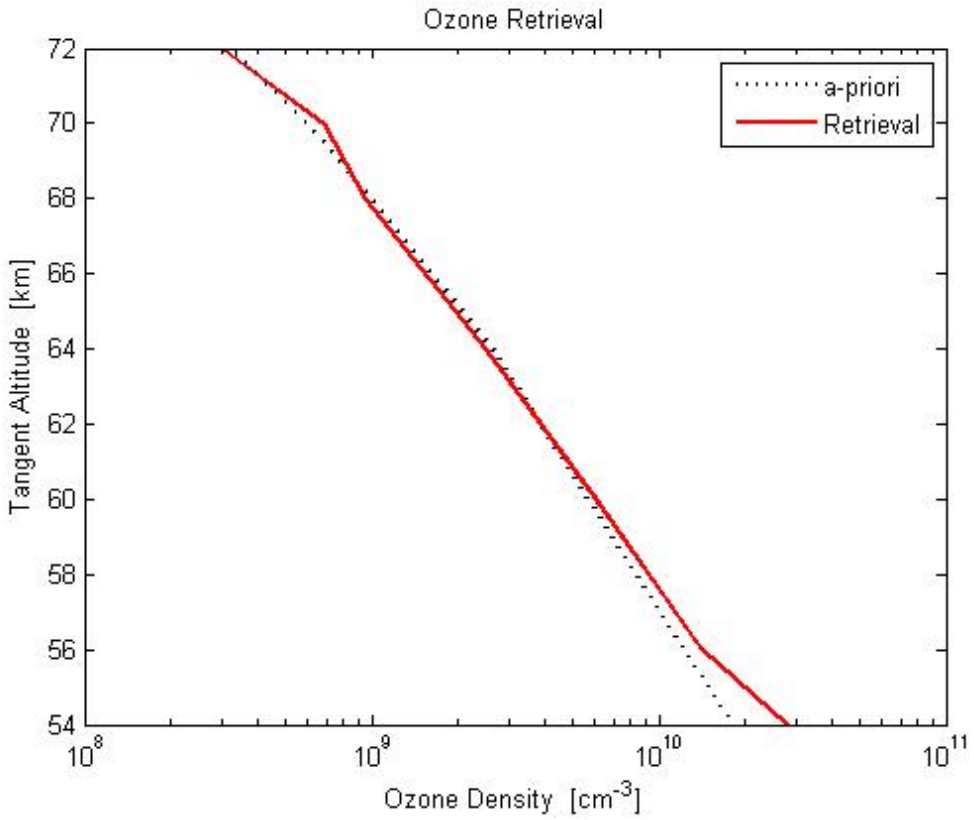

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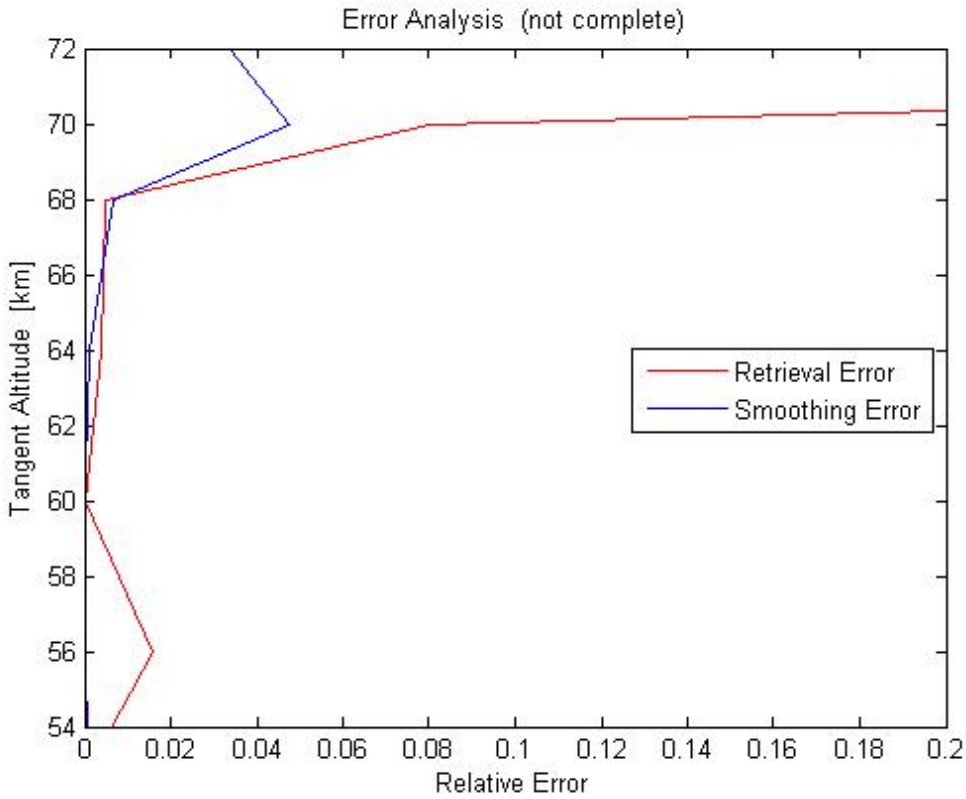

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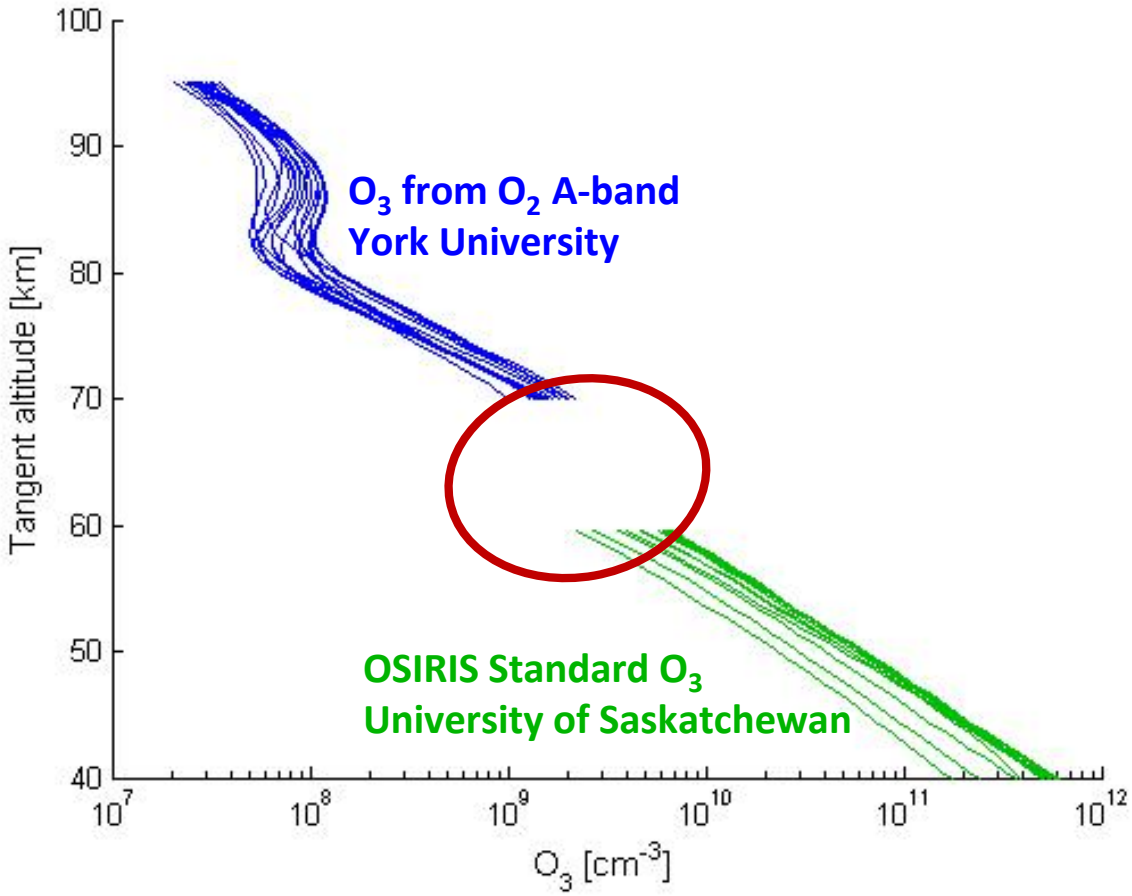

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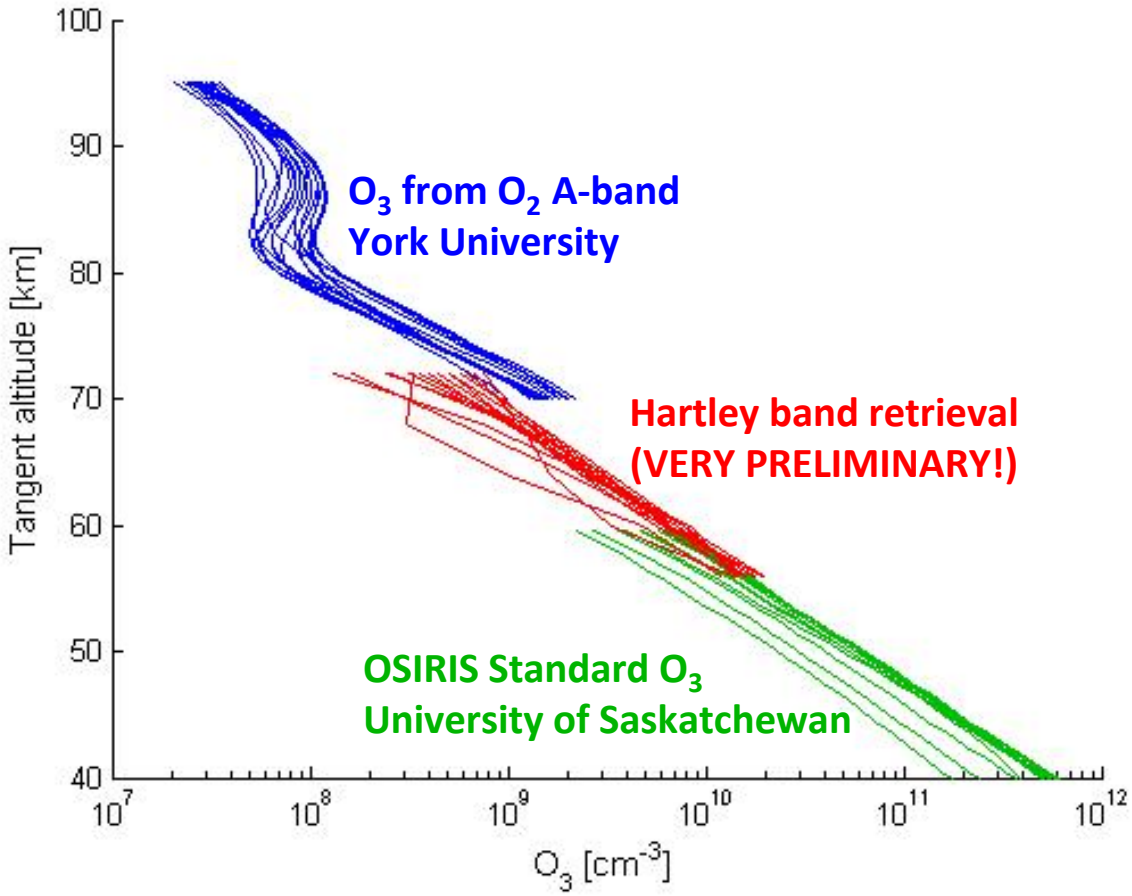

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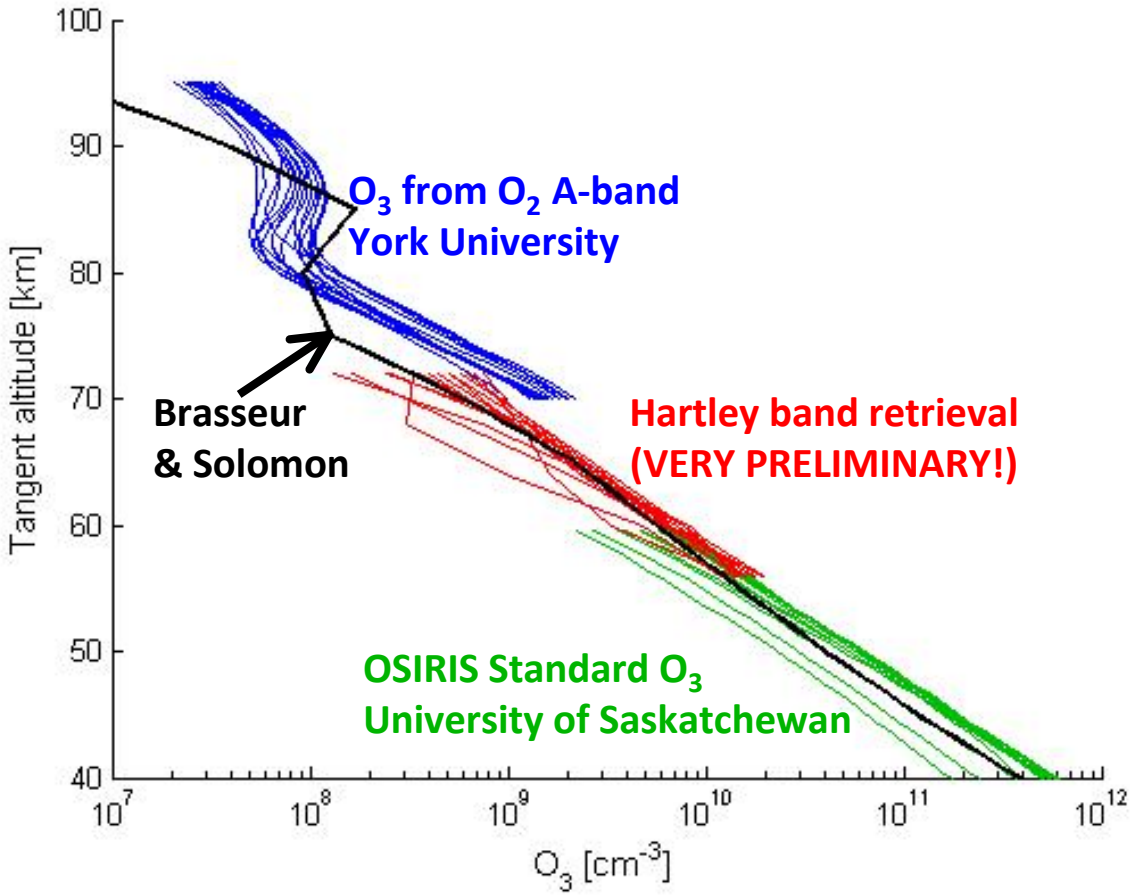

Conclusion/Outlook

- **We want a complete OSIRIS ozone product in the middle atmosphere**
- **The Hartley-Band retrieval is solely based on *relative* altitude variation of individual limb profiles**
- **Continue to improve the retrieval**

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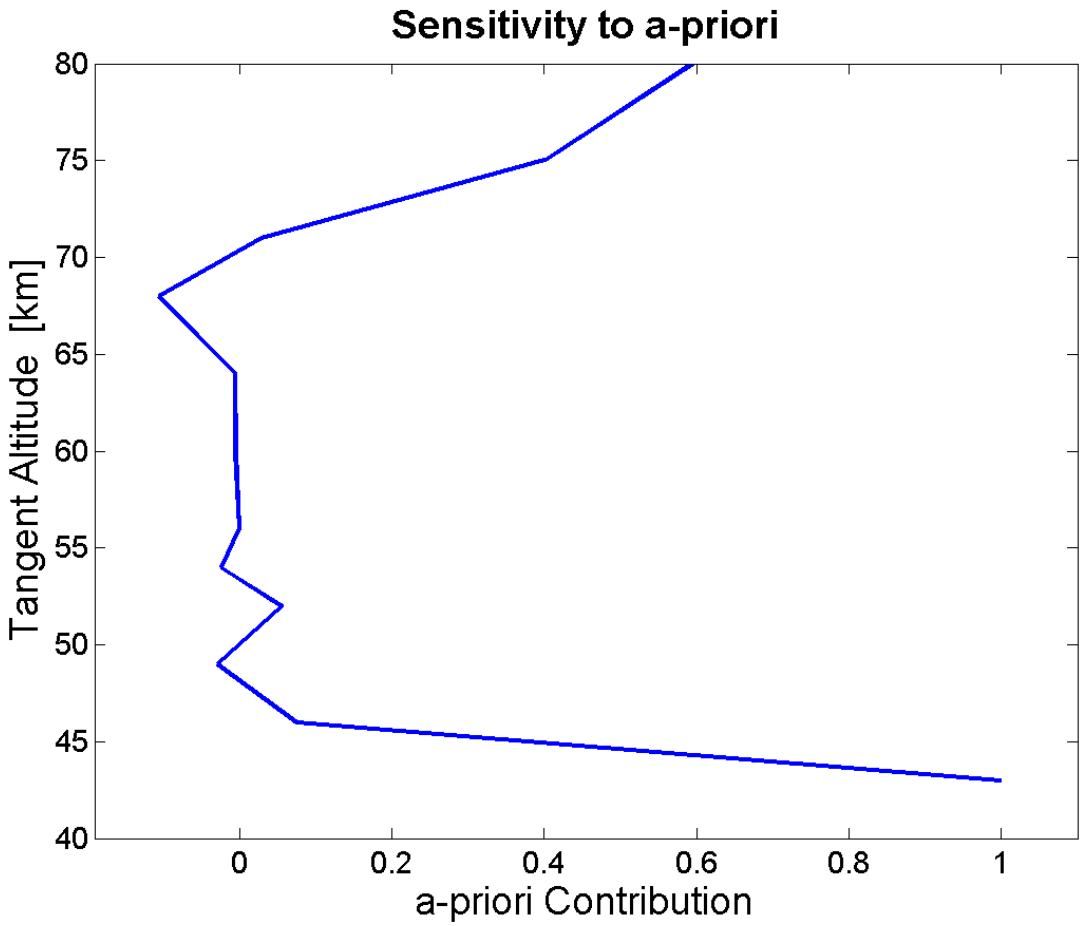
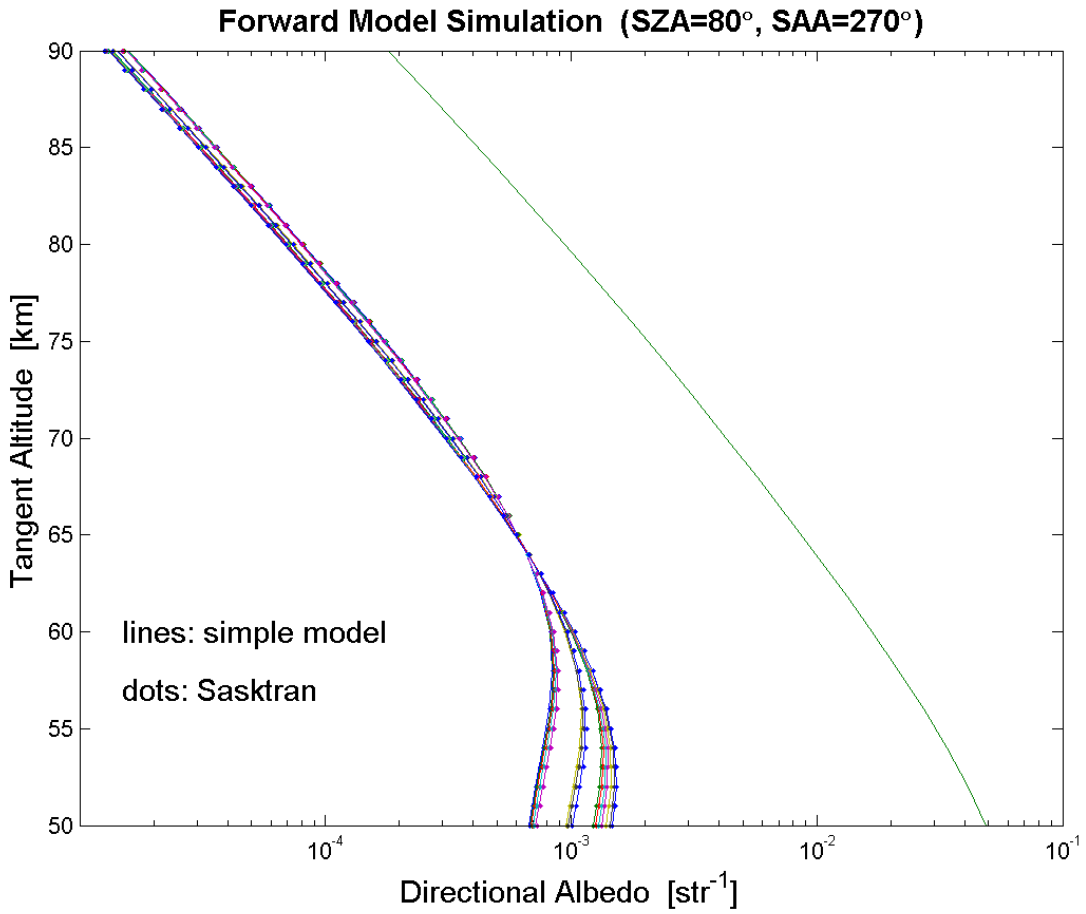
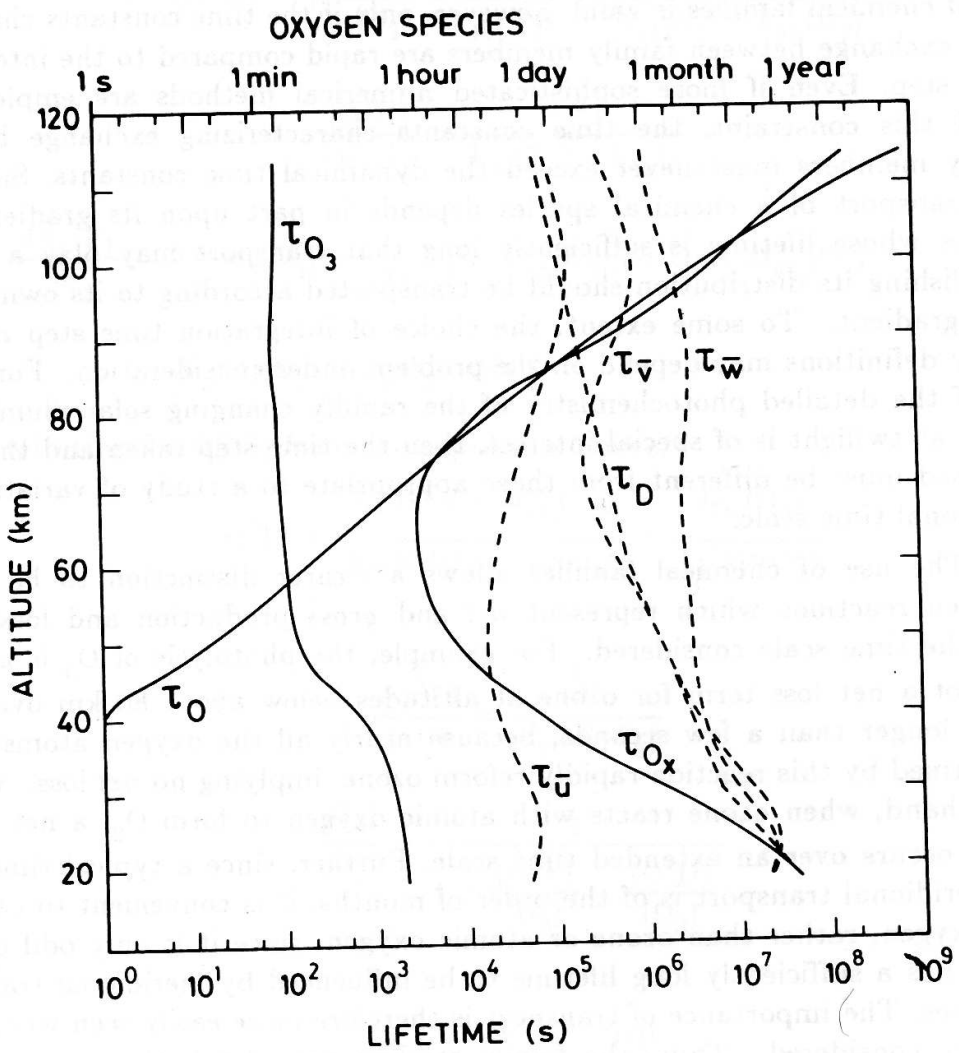
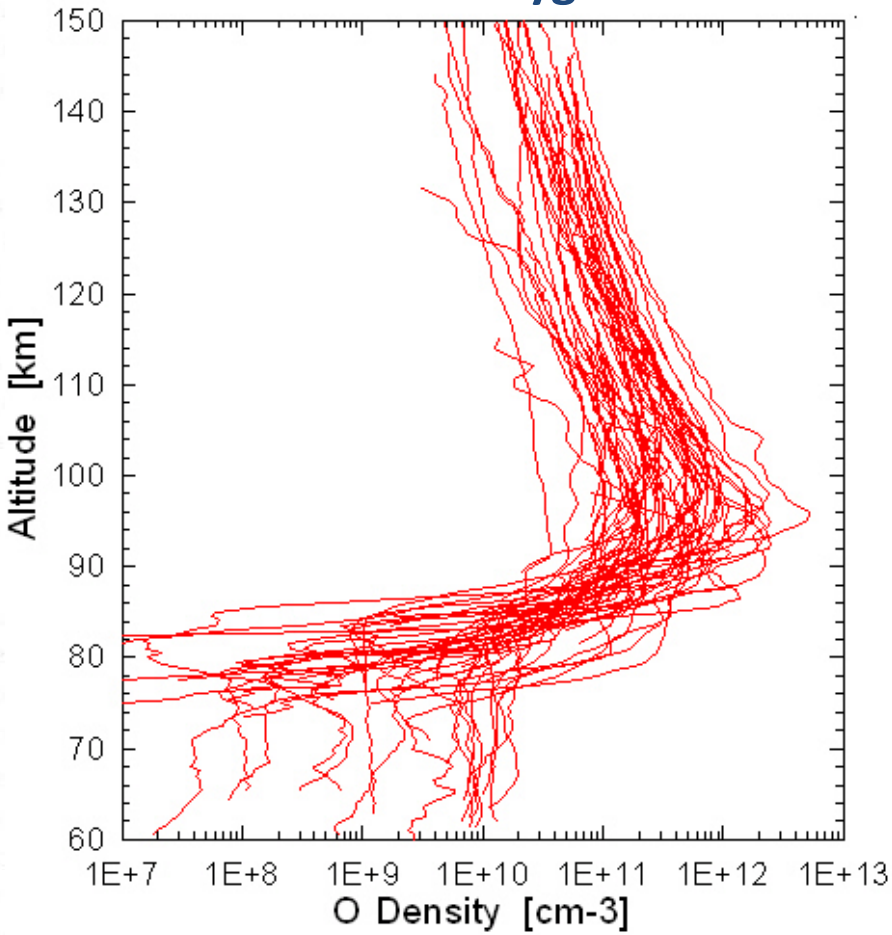
...any comments/suggestions are welcome


Sensitivity to a-priori
Tangent Altitude [km]
80
75
70
65
60
55
50
45
40
0
0.2
0.4
0.6
0.8
1
a-priori Contribution

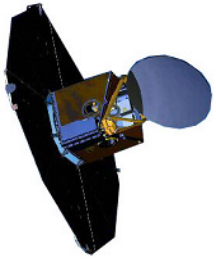

Forward Model Simulation (SZA=80°, SAA=270°)
Tangent Altitude [km]
90
85
80
75
70
65
60
55
50
lines: simple model
dots: Sasktran
10^-4
10^-3
10^-2
10^-1
Directional Albedo [str^-1]

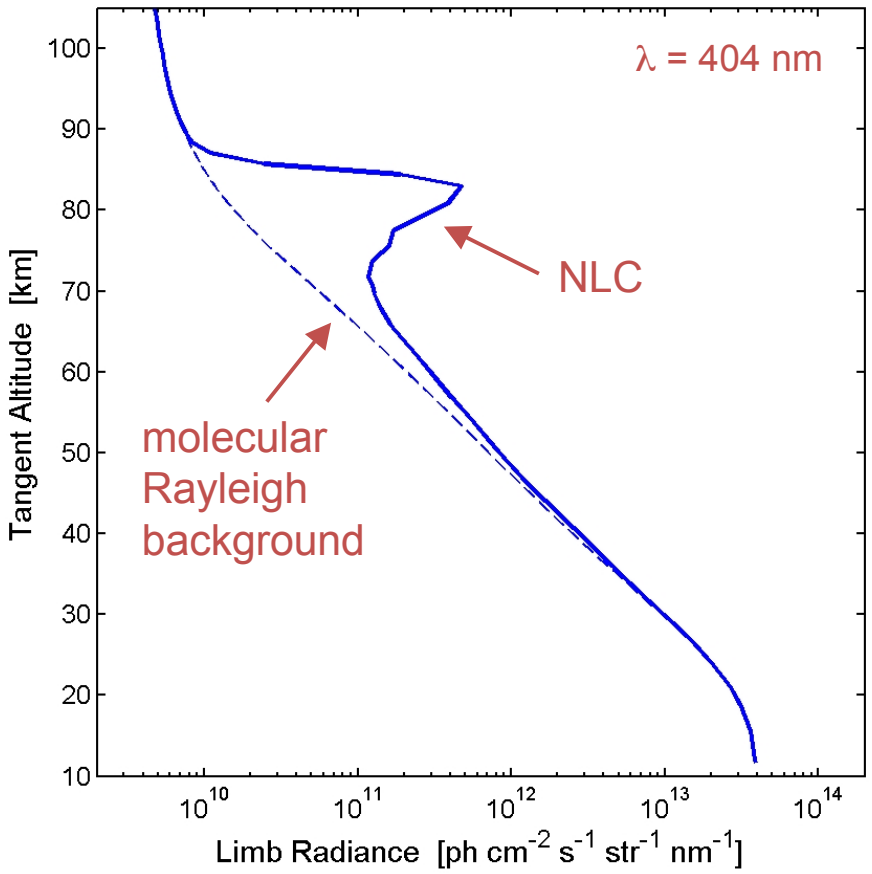


Rocket-borne Measurements of Atomic Oxygen



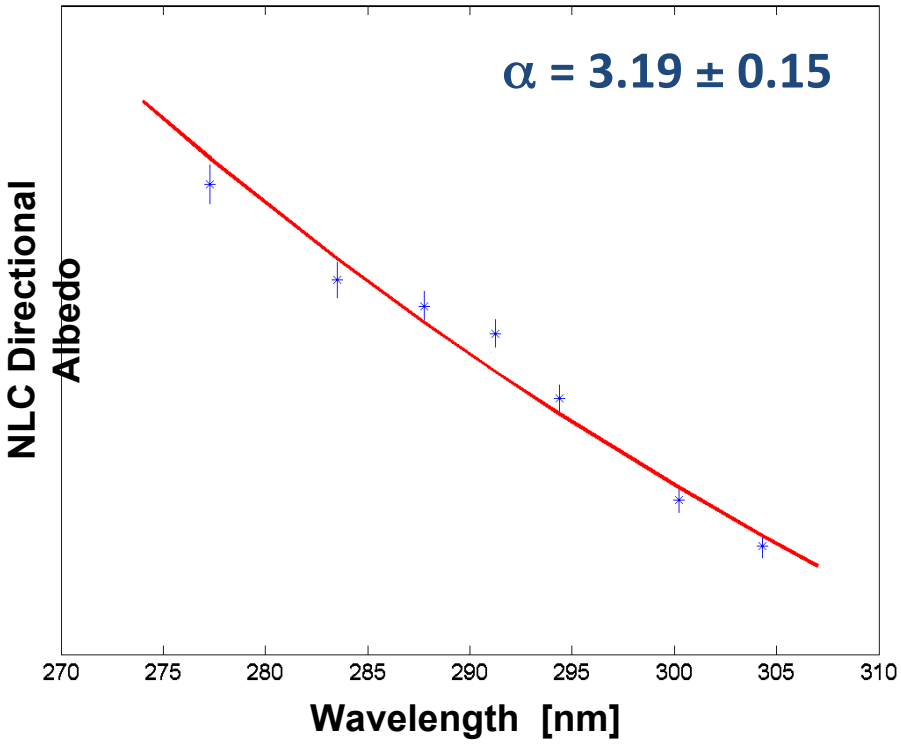
Effects on Limb Measurements of Noctilucent Clouds



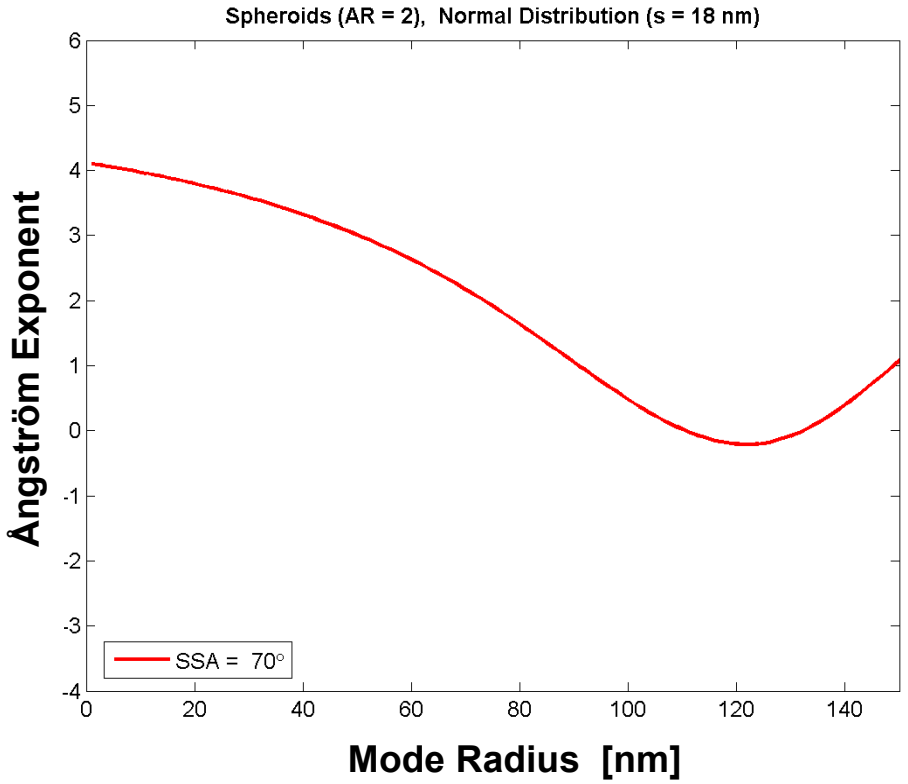


Size Analysis by Spectral Analysis in the UV

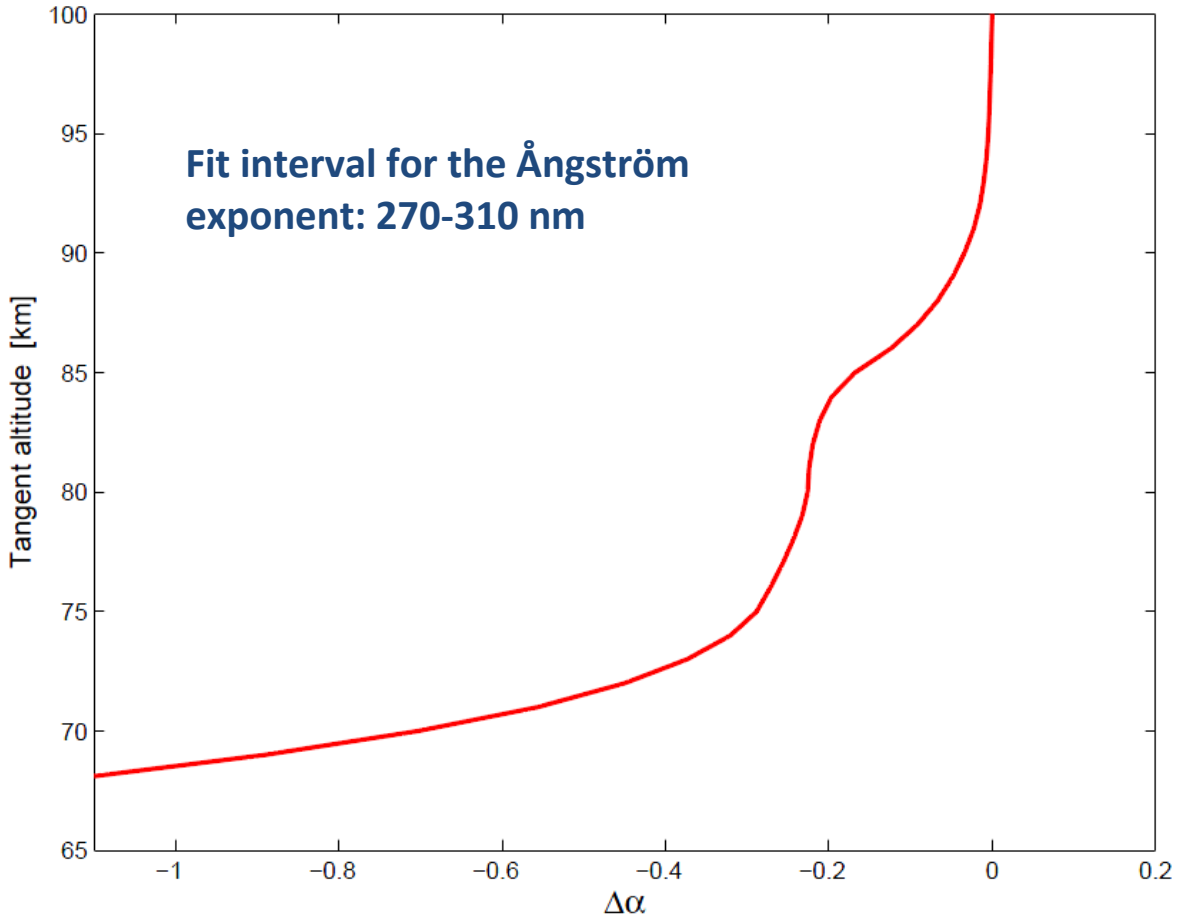
Ångström Fit to NLC Limb Data: scattering ~ $\lambda^{-\alpha}$



Size Retrieval by Comparison to Scattering Calculations (T-Matrix)



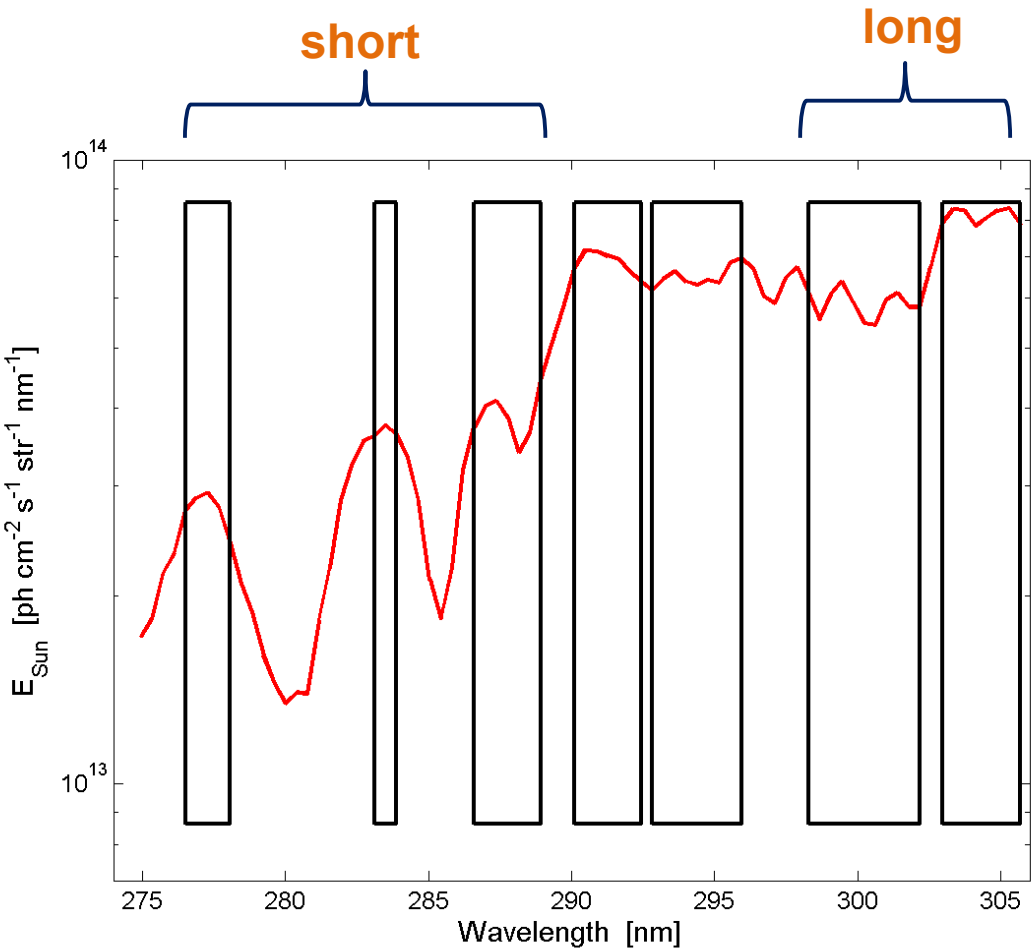
Influence of limb ozone absorption on the Ångström exponent:



Wavelength intervals free of airglow emissions etc.

Original choice of short and long wavelength intervals for ozone analysis

red: solar spectrum compilated in Saskatoon


short
long
10^{14}
10^{13}
E_{Sun} [ph cm^{-2} s^{-1} str^{-1} nm^{-1}]
275
280
285
290
295
300
305
Wavelength [nm]

Effect of ozone absorption on the limb scattering at the individual wavelength pixels within these intervals

Long wavelengths: Integrated effect over all pixels can be described with an effective absorption cross section corresponding to a single wavelength (red profile parallel to the blue profiles).

Short wavelengths: This does not work (red profile *not* parallel to the blue profiles).

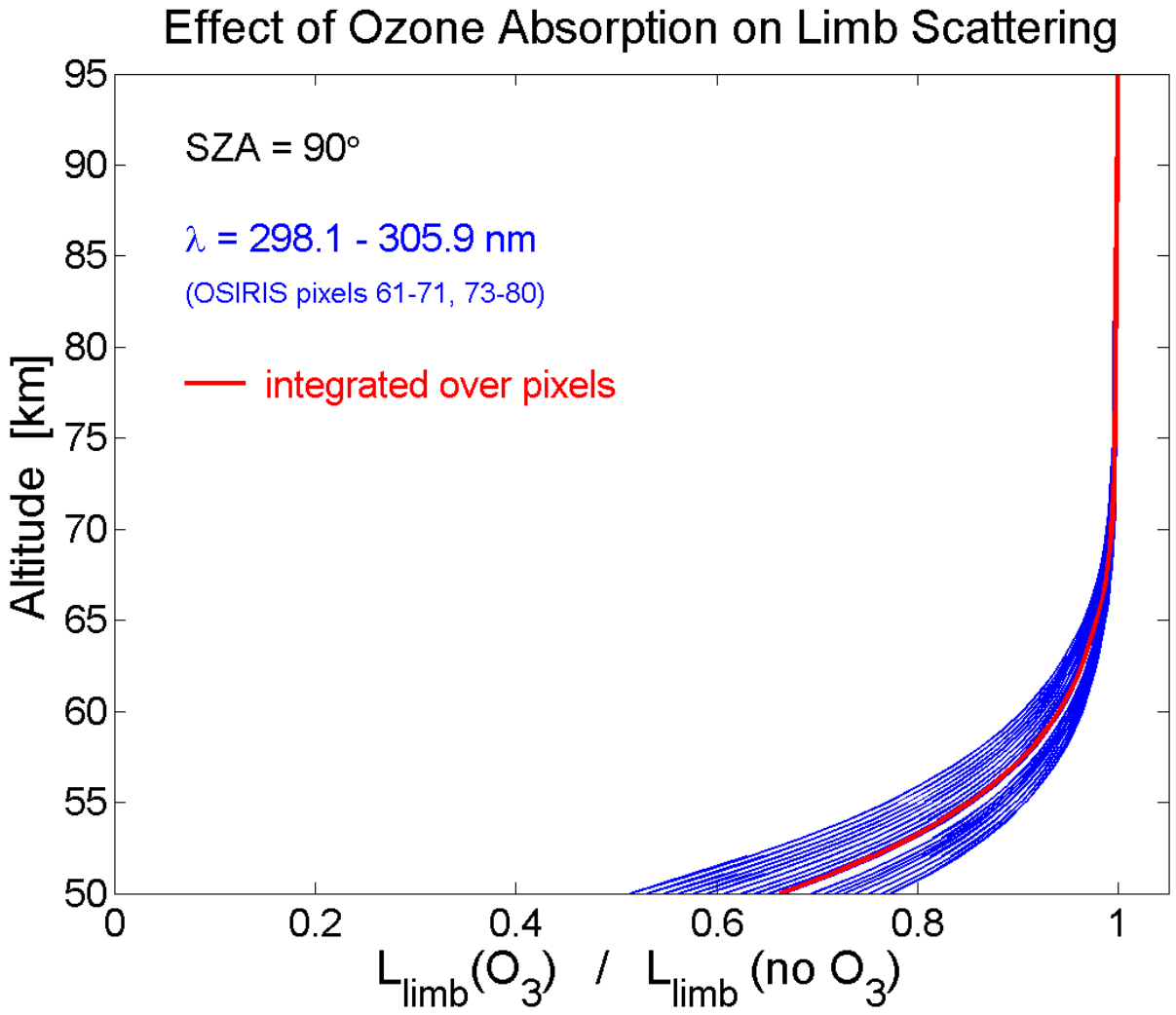
again:

model: SASKTRAN

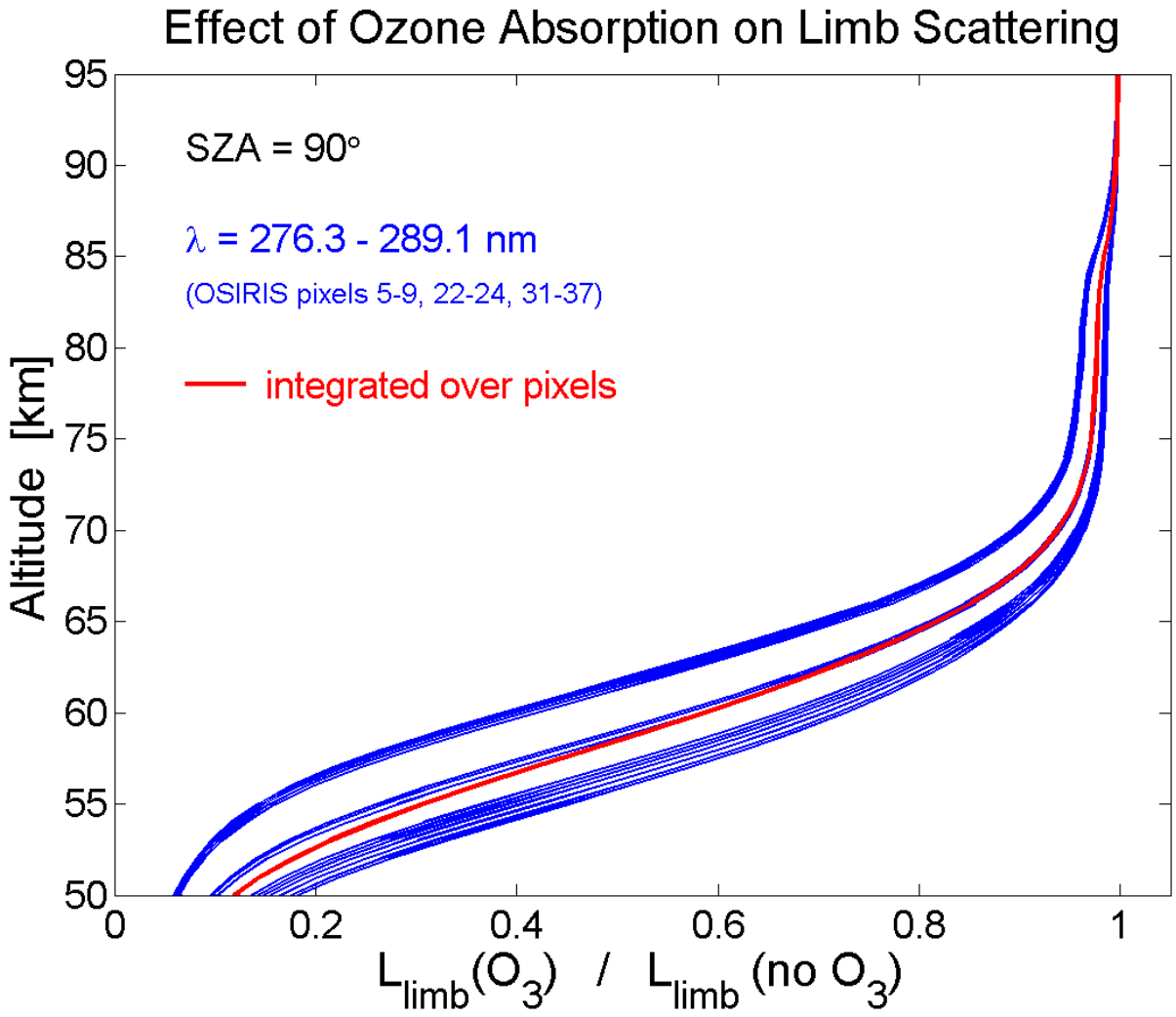
ozone profile: Brasseur & Solomon

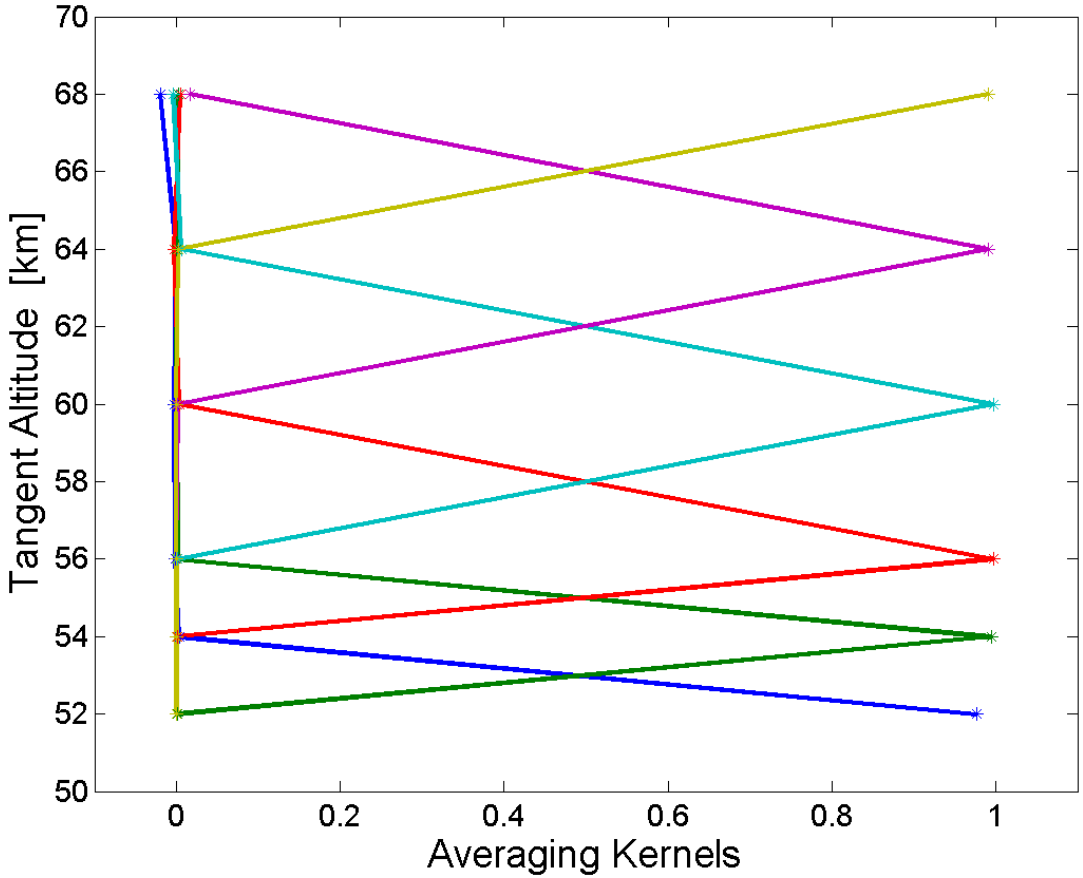
total density profile: MSIS, October, 50°N

Long wavelength intervals:



Short wavelength intervals:




70
68
66
64
62
60
58
56
54
52
50
Tangent Altitude [km]
0
0.2
0.4
0.6
0.8
1
Averaging Kernels