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SCIAMACHY

esa
European Space Agency

Recent changes in Stratospheric NO_2 using CTMs and satellite observations

E. Galytska[1], M.P. Chipperfield[2] , A.Rozanov[1], S. Dhomse[2], J.P. Burrows[1]

1- Institute of Environmental Physics, University of Bremen, Bremen, Germany
2- School of Earth and Environment, University of Leeds, Leeds LS2 9JT, UK

Spatio-temporal modeling of stratospheric NO_2

My PhD project comprises:

- Acquaintance with CTMs: B3DCTM and TOMCAT/SLIMCAT, establish models inter-comparison
- Validation of stratospheric NO_2 and development of advanced photochemical conversion scheme, needed due to its strong diurnal variation.
- Decadal NO_2 changes in tropical stratosphere, their impact on O_3, and assess systematic uncertainties with the application of modeling approaches in order to interpret the observations.

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CTMs:

Chemical Transport Models

B3DCTM & SLIMCAT

3-D numerical models that simulate processes to describe the spatio-temporal variability chemical compounds in the atmosphere, using meteorological information as input.

Short overview

- B3DCTM - Bremen 3 Dimensional Chemistry Transport Model
- 2002 – nowadays - B3DCTM is in the Institute of Environmental Physics (IUP), Bremen University.

Models intercomparison:

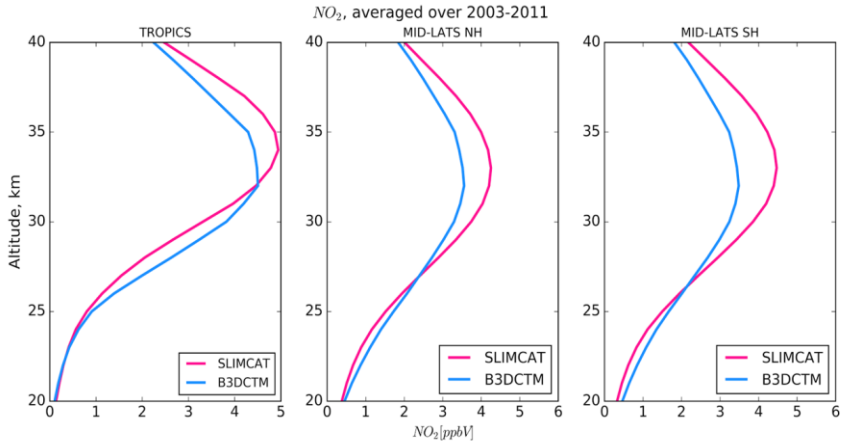
- Time period: 1980-2011
- Compared species : O_3, NO_2, N_2O, NO, NO_3, HNO_3, N_2O_5, NO_y (NO_2 +NO+ NO_3 + H NO_3 + 2 N_2O_5), BrO
- Both, B3DCTM and SLIMCAT use ECMWF ERA-Interim reanalysis

B3DCTM vs. SLIMCAT

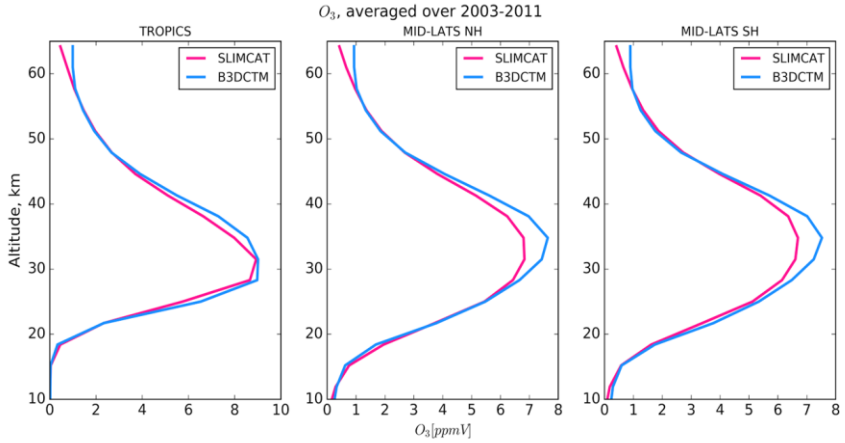
Time period:2003-2011	
Meteorology: ECMWF Era-Interim (E-I) reanalysis	
Vertical transport	
E-I heating rates	divergence of horizontal mass flux

3 latitude bands:
Tropics (20°S-20°N)
Middle latitudes (ML):
NH (35°-60°N), SH (35°-60°S)

NO_2



O_3



SCIAMACHY
March 2002–April 2012

Orbit: sun-synchronous, ~800 km

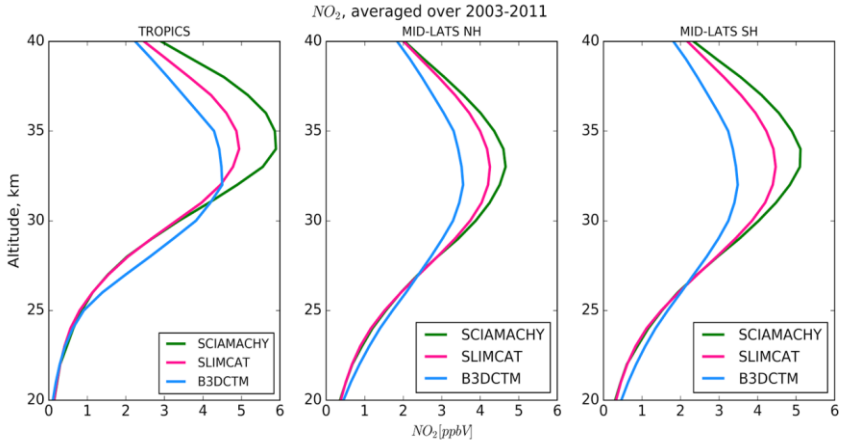
Spectral range: 214 – 2386 nm

Spectral resolution: 0.22 – 1.48 nm

Measurement modes

- Limb
- Nadir
- Occultation

NO_2



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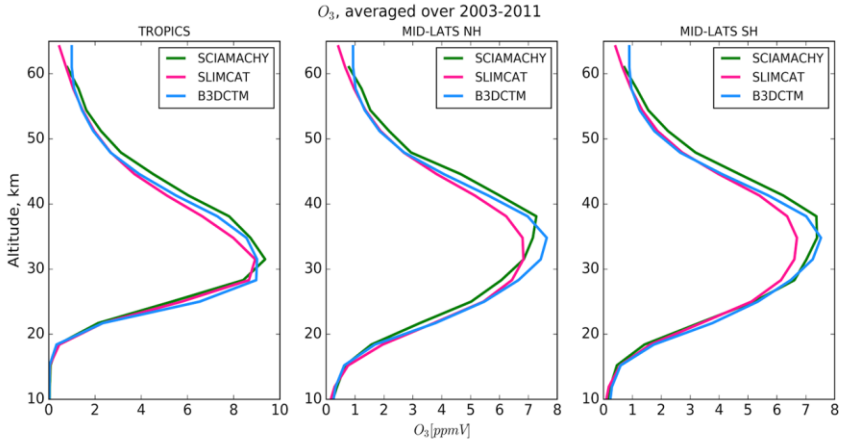

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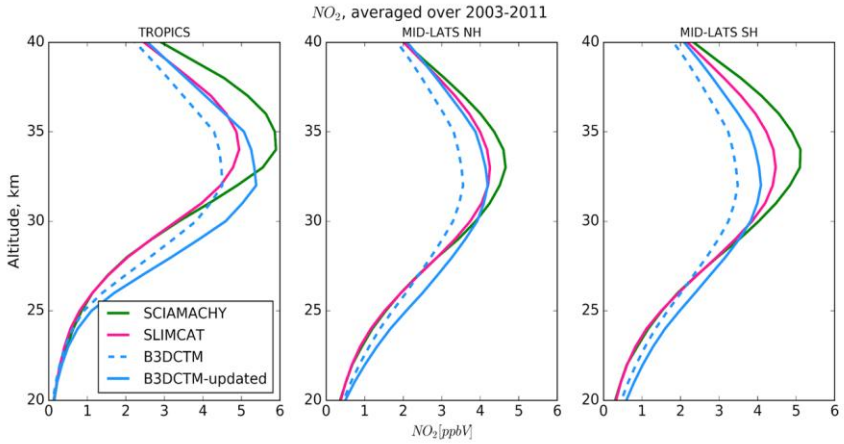

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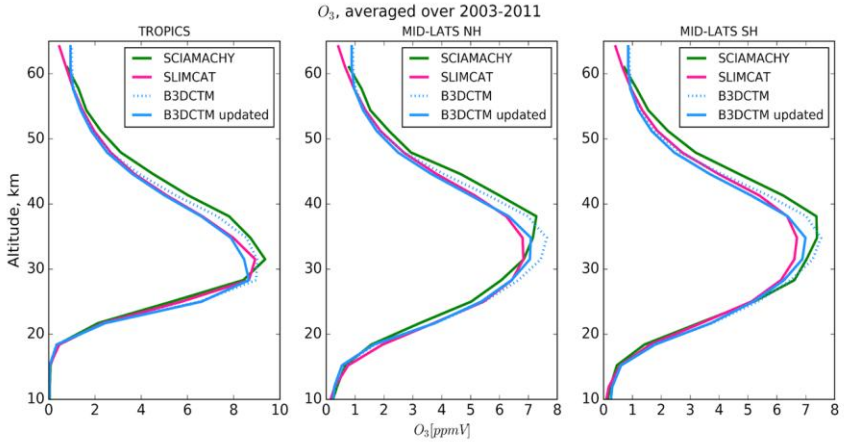

MIPAS
March 2002–April 2012

The **M**ichelson **I**nterferometer for **P**assive **A**tmospheric **S**ounding

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Spectral range: 4.15 – 14.6 µm

Measurement modes

Limb

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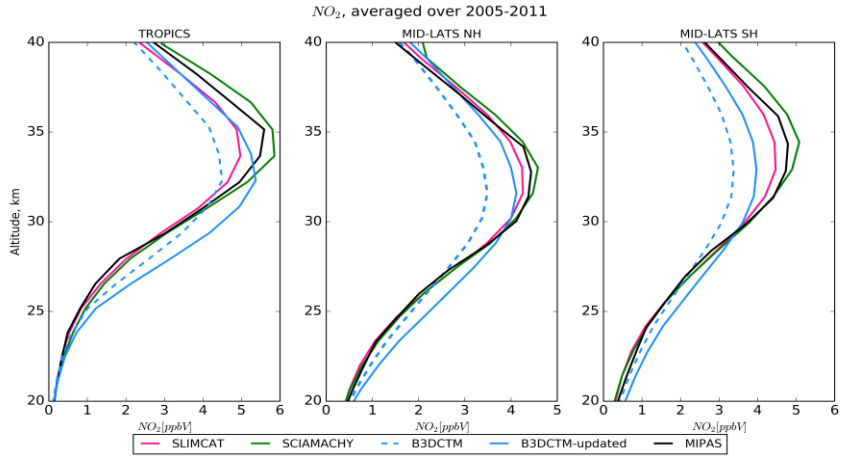
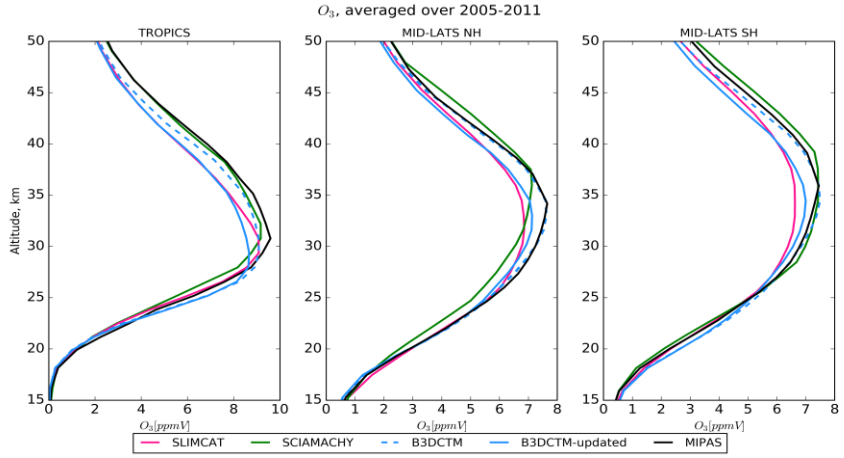


O_3



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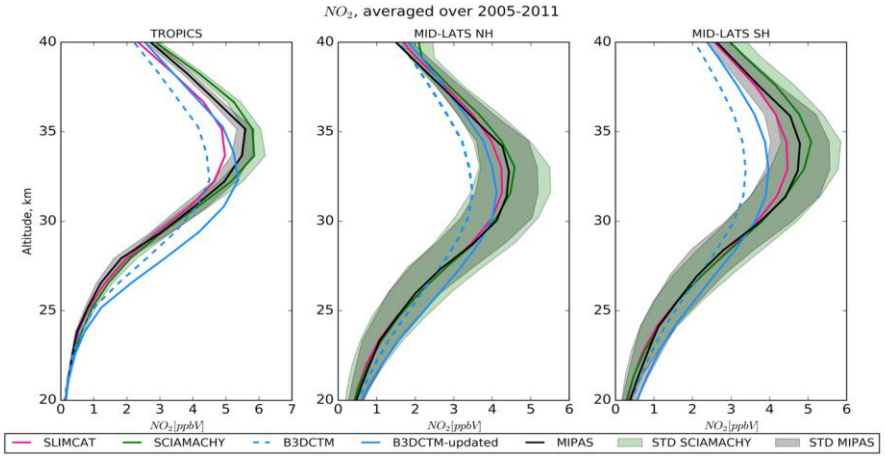

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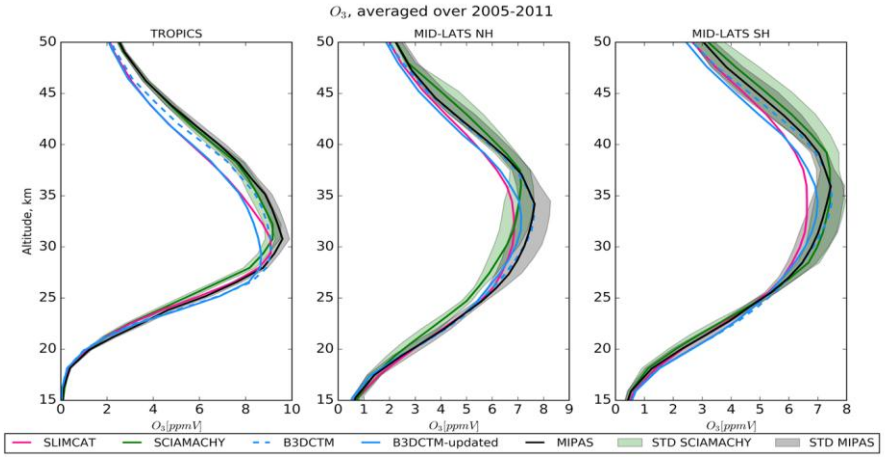

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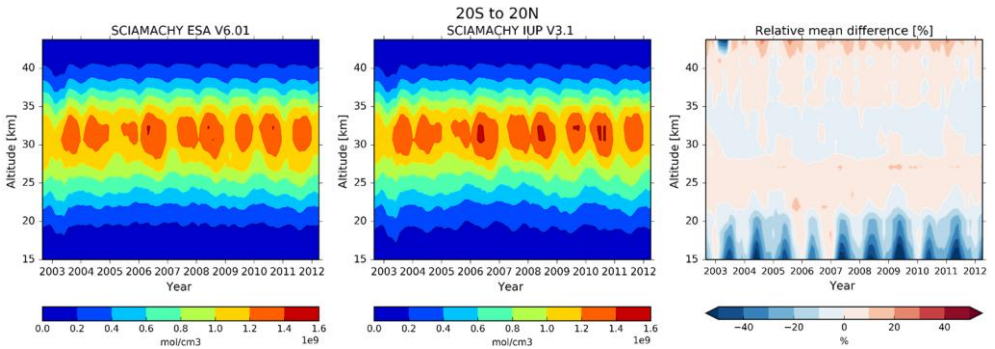
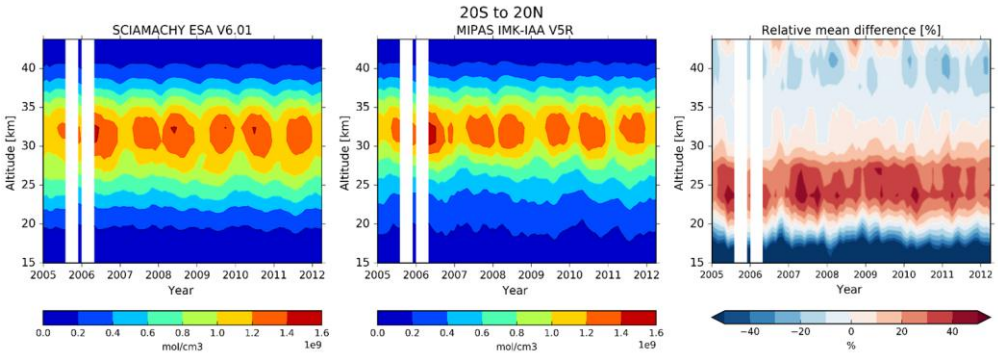
NO_2 validation: comparison of Limb measurements

SCIAMACHY ESA - SCIAMACHY IUP

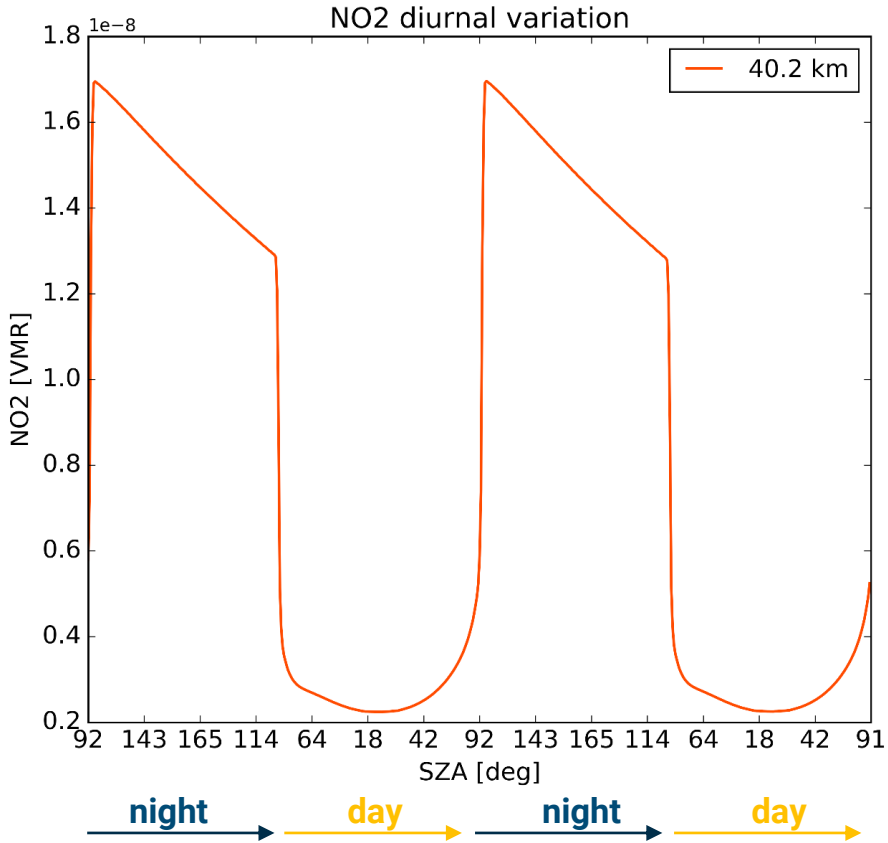


SCIAMACHY ESA - MIPAS IMK



Limb vs. occultation?

NO_2 validation: accounting for differences in the local solar time



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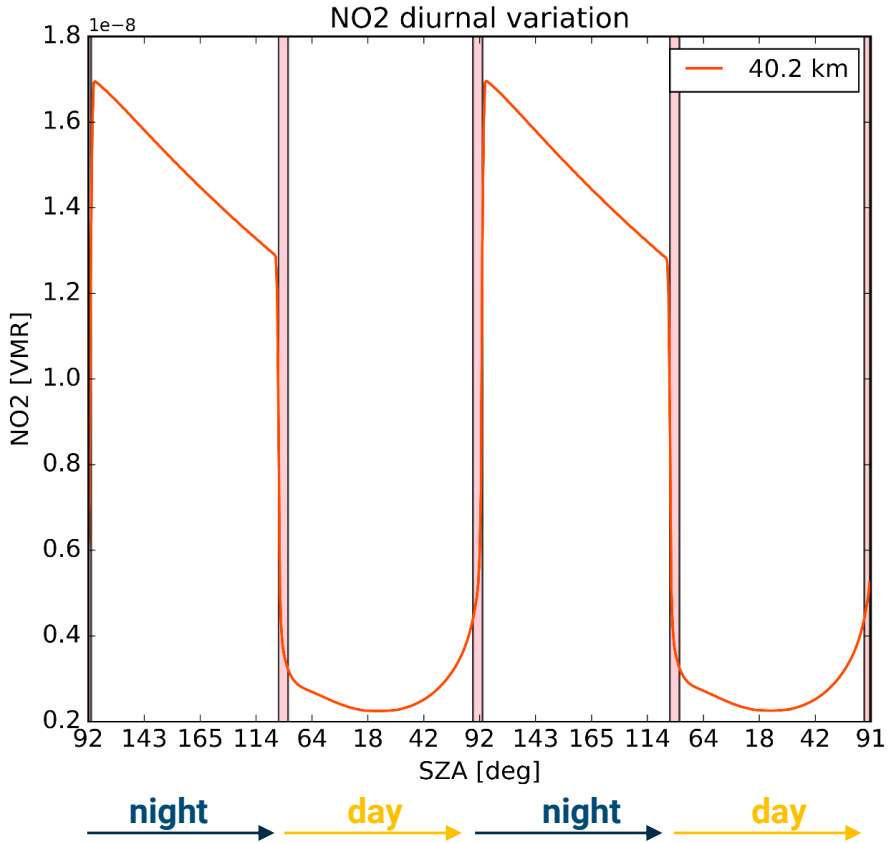

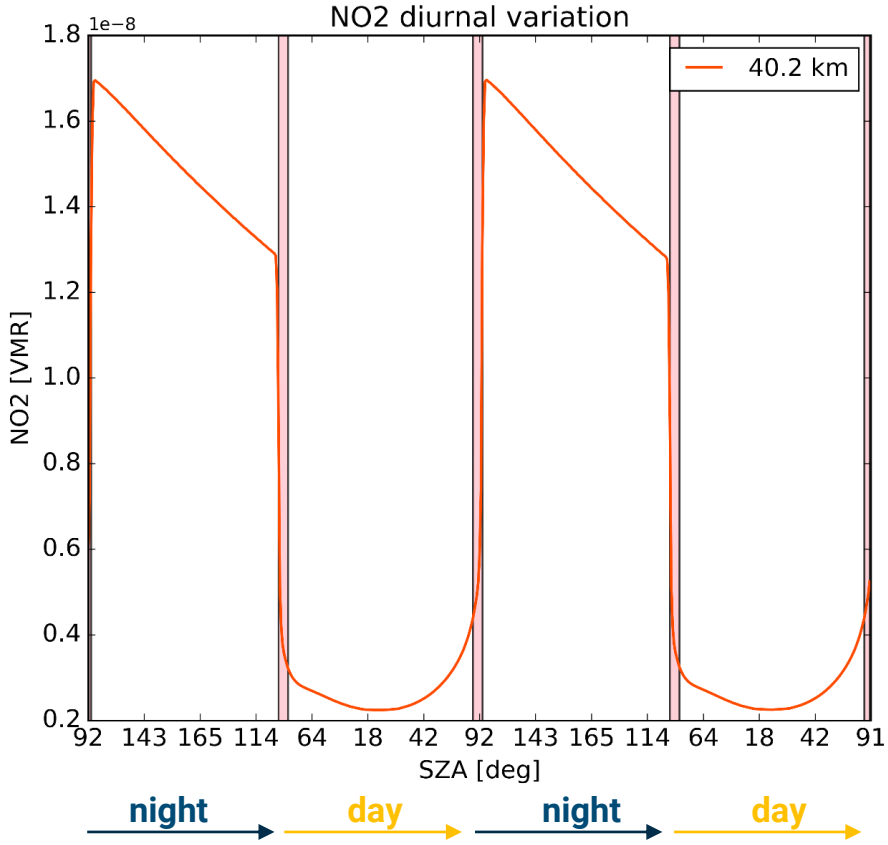
NO2 diurnal variation
1e−8
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
NO2 [VMR]
40.2 km
92 143 165 114 64 18 42 92 143 165 114 64 18 42 91
SZA [deg]
night
day
night
day

$NO + O_3 \rightarrow NO_2 + O_2$

$NO_2 + O_3 \rightarrow NO_3 + O_2$
$NO_2 + NO_3 + M \rightarrow N_2O_5 + M$
$NO_2 + OH + M \rightarrow HNO_3 + M$

$N_2O_5 + hv \rightarrow NO_2 + NO_3$
$HNO_3 + hv \rightarrow NO_2 + HO$
$NO_3 + hv \rightarrow NO_2 + O$
$NO_2 + hv \rightarrow NO + O\ (^3P)$

NO_x

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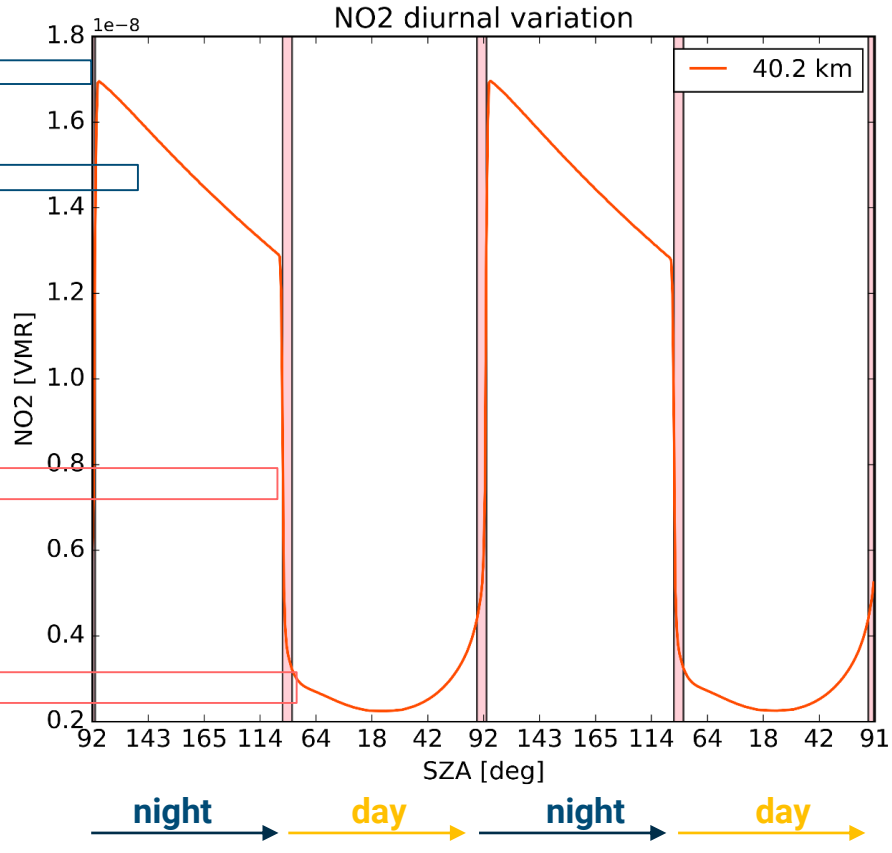
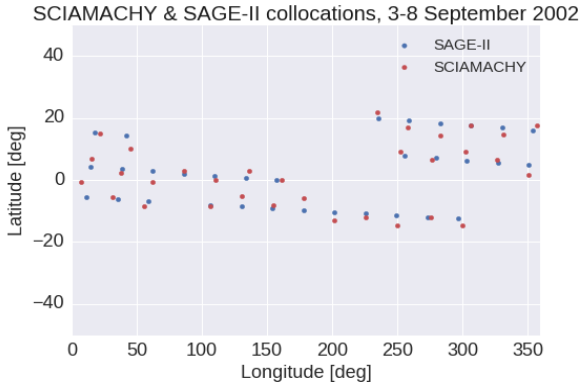


SCIAMACHY vs. SAGE-II: Limb vs. Occultation
How do we do it?

1. Run SLIMCAT with output on SAGE-II locations & Define collocated SCIAMACHY-SAGE-II profiles (8 h and 500 km)



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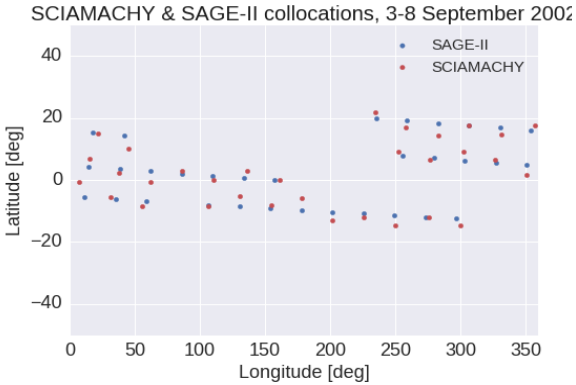

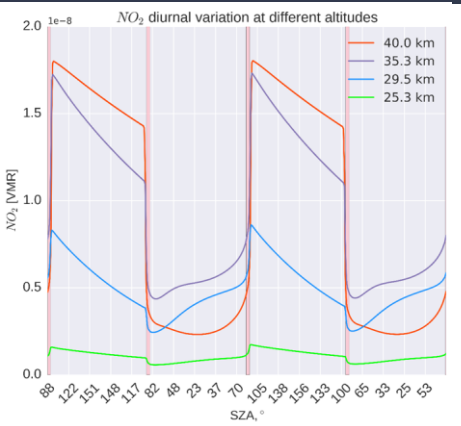

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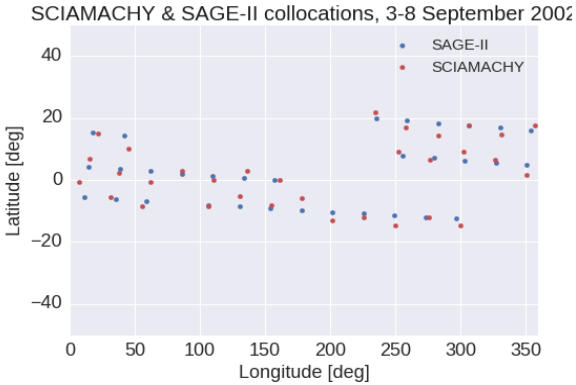
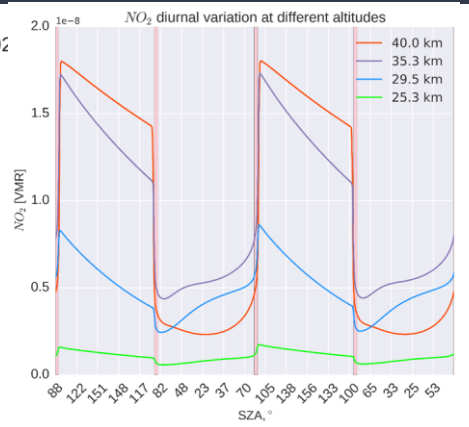
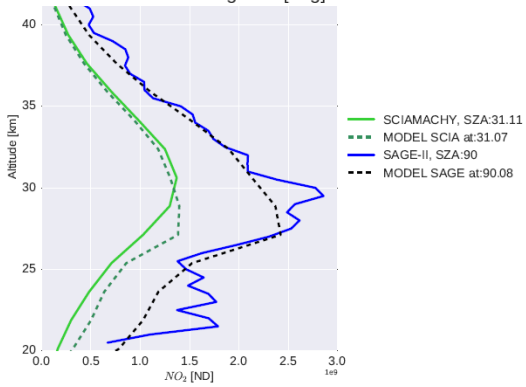
$$F = \text{mod } NO_{2\,SCIA} / \text{mod } NO_{2\,SAGE\text{-}II}$$







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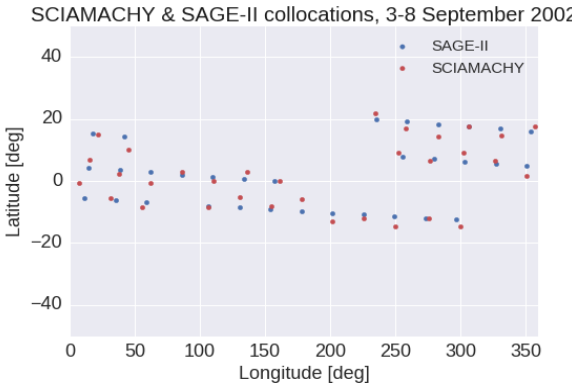

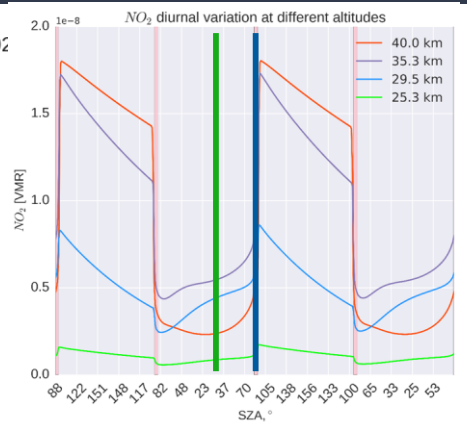

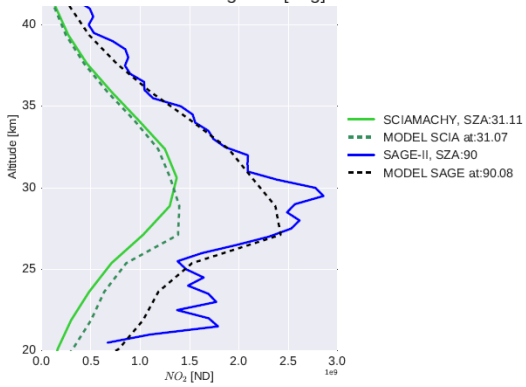

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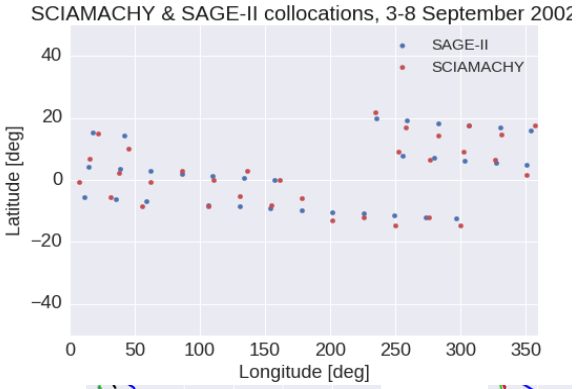
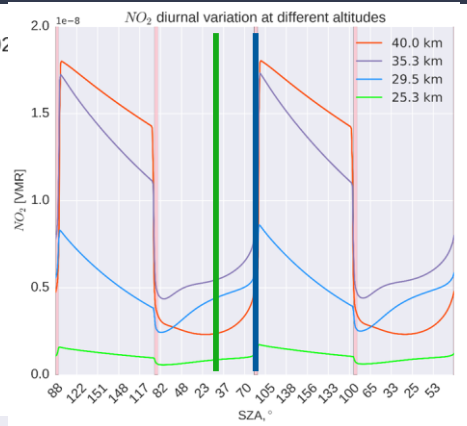
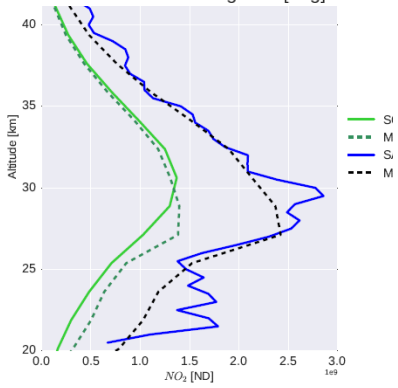
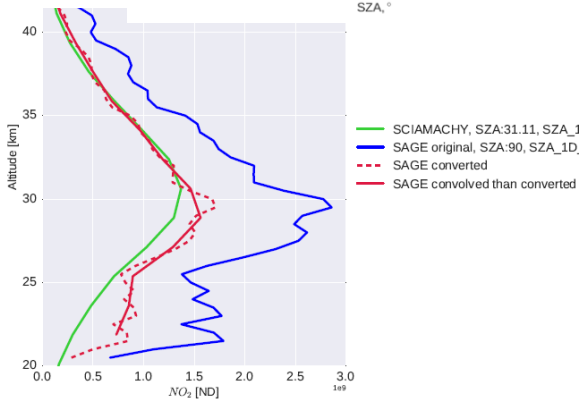
4. Apply F to SAGE-II measurements to scale to SCIAMACHY SZA

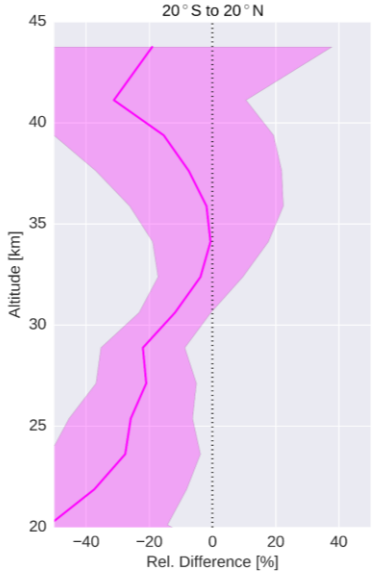


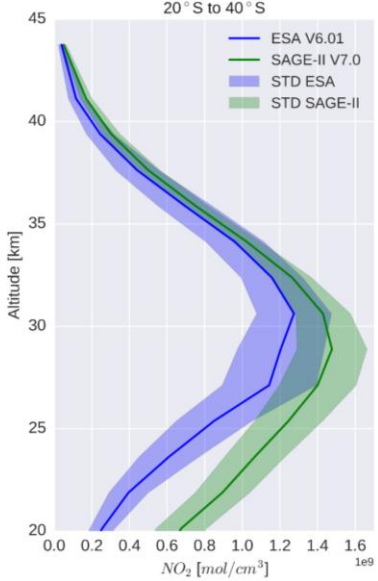


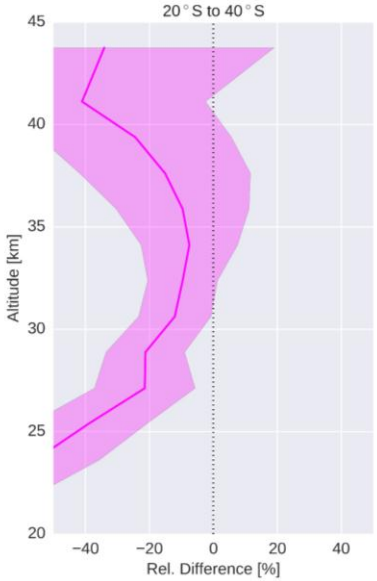




SCIAMACHY vs. SAGE–II : Photochemically converted profiles







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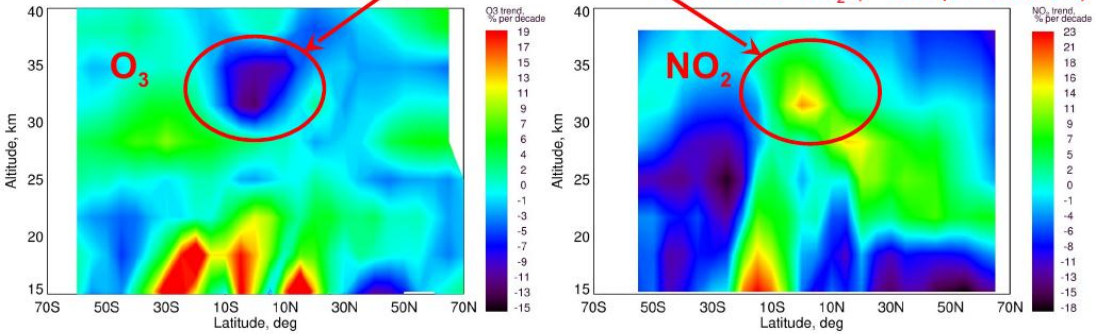
Highly correlated with increased VMRs of NO_2 (~18% per decade)



SCIAMACHY O_3 and NO_2 trends in the tropical stratosphere, 2004-2012

* From the presentation of Dr. A. Rozonov, 9th Workshop on Long Term Changes and Trends, Kuhlungsborn, Germany, 19-23 September 2016

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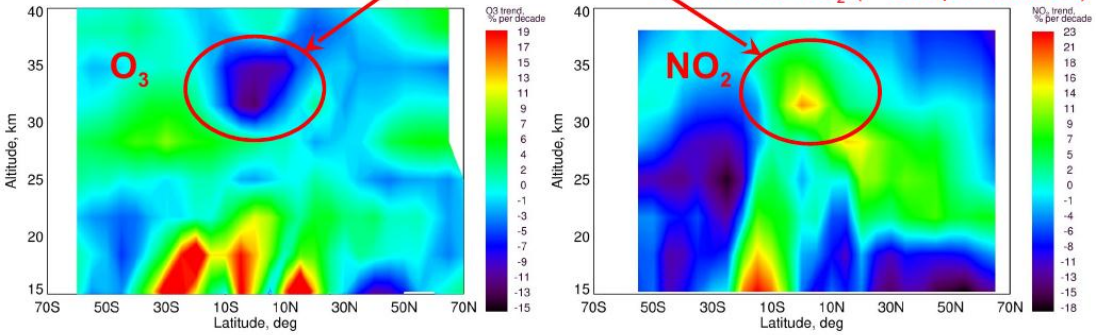
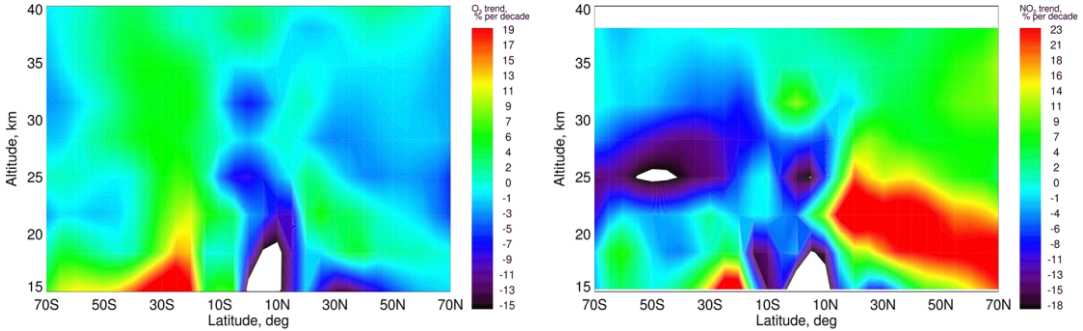


SLIMCAT



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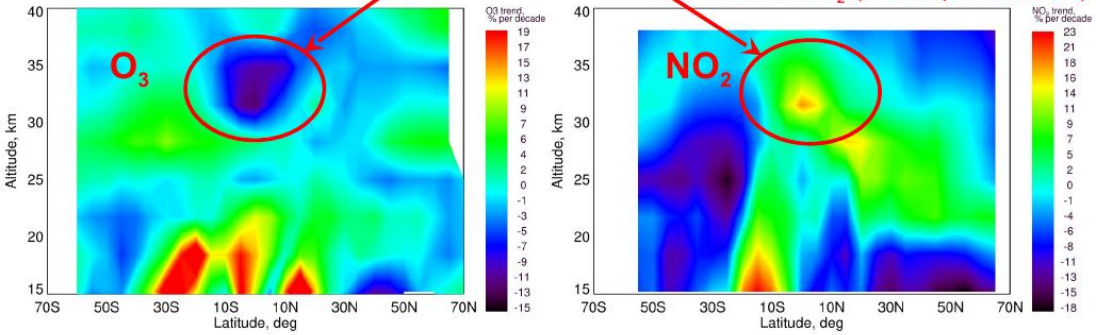

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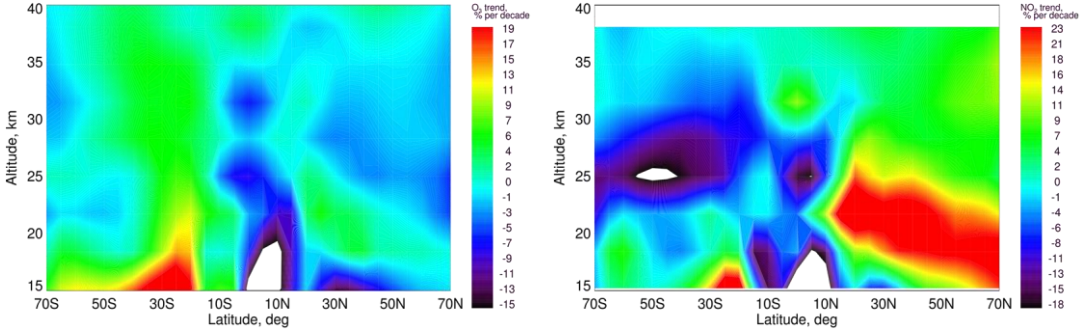
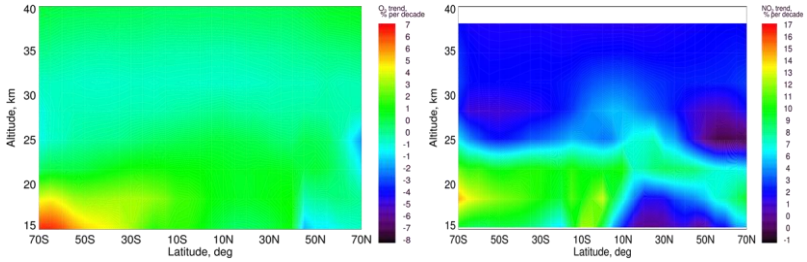


SLIMCAT with fixed dynamics

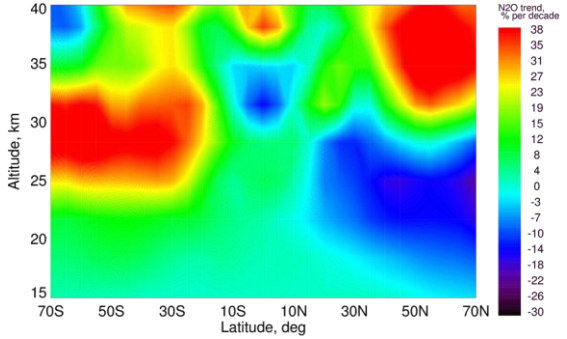
O_3 NO_2



Decadal NO_2 and O_3 changes in tropical stratosphere

Decadal NO_2 and O_3 changes in tropical stratosphere

N_2O



Slower tropical upwelling

↓

Longer residence time of N_2O

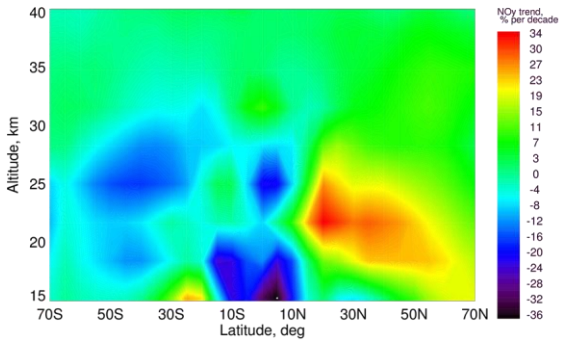
↓

More NO_y

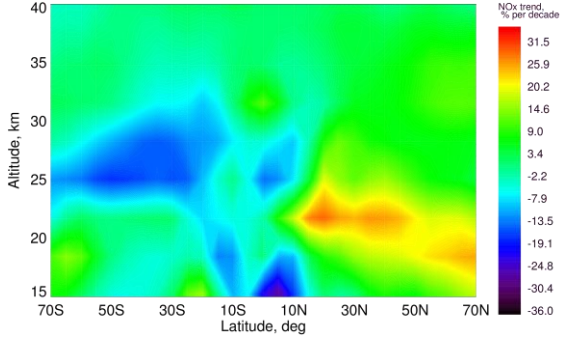
↓

Less O_3

NO_y



NO_x



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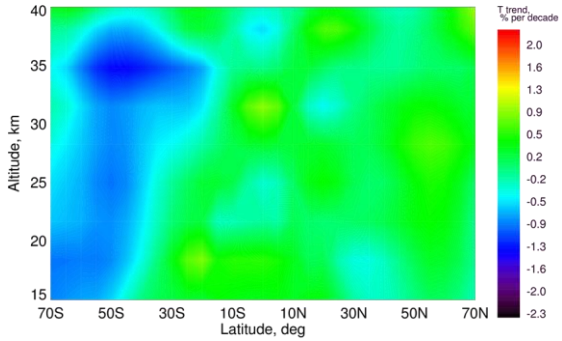

Small positive trend in T

Positive NO_2 trend comes from the positive NO_y trend

Further steps:

- Analyze SLIMCAT simulation with fixed concentrations of source gases
- Intercompare transport patterns by means of Age of Air and MIPAS SF-6