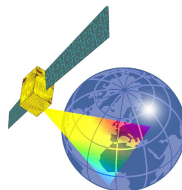


Investigation of Horizontal Inhomogeneity Effects on Aerosol Limb Retrievals Using 2D Radiative Transfer Simulations

Steffen Dörner, Janis Puķīte, Sven Kühn, Marloes Penning de Vries, Thomas
Wagner

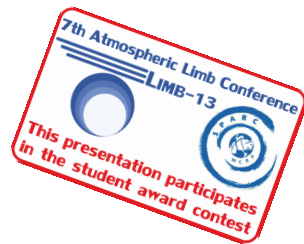


MAX-PLANCK-INSTITUT
FÜR CHEMIE



Satellite Remote
Sensing

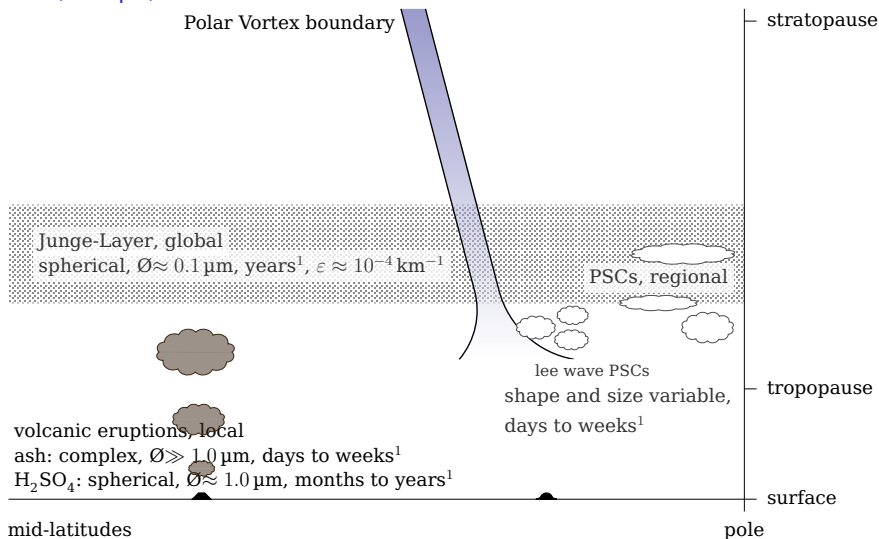
Max Planck Graduate Center 
mit der Johannes Gutenberg-Universität Mainz



19th June 2013

Stratospheric Particles

Horizontal Scale, Shape, Size and Lifetime



¹ Source for particle size/life times: [Liu et al., 2001; Schreiner et al. 2001; Thomason, L. W., and T. Peter 2006]

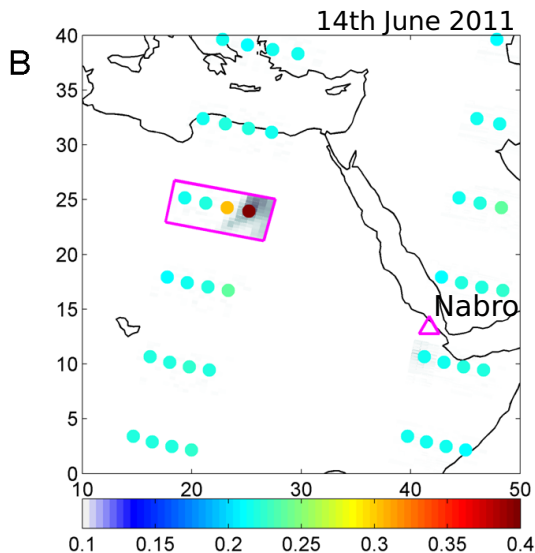
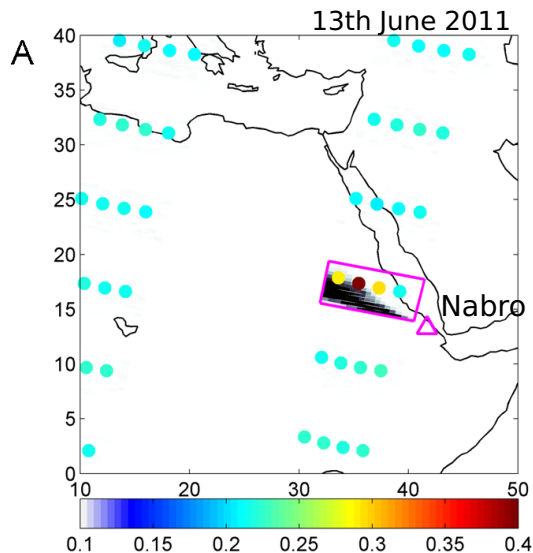
Influence on:

- Ozone Layer (heterogeneous chemistry)
- Radiation Budget

Example for Horizontal Inhomogeneity

SCIAMACHY measurements of a volcanic plume

- : Limb Color-Index at a tangent height of 18.5 km (tangent point coord.)
- : Nadir SO₂ column density



Source: Penning de Vries et al., in prep

The Retrieval Method

An onion peeling approach to retrieve Aerosol extinction

$$I_{\text{sim}}(\lambda, TH) \stackrel{!}{=} I_{\text{meas}}(\lambda, TH)$$

- Wavelength dependent variation of the extinction
⇒ Single wavelength retrieval

The Retrieval Method

An onion peeling approach to retrieve Aerosol extinction

$$\frac{I_{\text{sim}}(\lambda, TH)}{I_{\text{sim}}(\lambda, TH_{\text{ref}})} \stackrel{!}{=} \frac{I_{\text{meas}}(\lambda, TH)}{I_{\text{meas}}(\lambda, TH_{\text{ref}})}$$

- Wavelength dependent variation of the extinction
⇒ Single wavelength retrieval
- Comparability of instrumental calibration and simulation output
⇒ Keep tangent height normalization!

The Retrieval Method

An onion peeling approach to retrieve Aerosol extinction

$$\frac{I_{\text{sim}}(\lambda, TH)}{I_{\text{sim}}(\lambda, TH_{\text{ref}})} \stackrel{!}{=} \frac{I_{\text{meas}}(\lambda, TH)}{I_{\text{meas}}(\lambda, TH_{\text{ref}})}$$

- Wavelength dependent variation of the extinction
⇒ Single wavelength retrieval
- Comparability of instrumental calibration and simulation output
⇒ Keep tangent height normalization!

Retrieval of the extinction ε at each tangent height (TH), starting at the layer below the reference tangent height (TH_{ref}) using the following approach:

$$\frac{\partial I(TH)}{\partial \text{ext}(TH)} = \underbrace{\left(\frac{I_{\text{sim/meas}}(TH)}{I_{\text{sim/meas}}(TH_{\text{ref}})} - \frac{I_{\text{sim,ray}}(TH)}{I_{\text{sim,ray}}(TH_{\text{ref}})} \right)}_{\Delta I_{\text{sim/meas}}(TH)} \cdot (\varepsilon(TH) - \varepsilon_{\text{ray}}(TH))^{-1}$$

Iterative process starting at $\varepsilon_0 = 0 \text{ km}^{-1}$, using

$$\varepsilon_{n+1} = \Delta I_{\text{meas}} \cdot \frac{\varepsilon_n}{\Delta I_{\text{sim}}}$$

The Retrieval Method

Retrieval result:

- Retrieve extinction profile from measured intensity profile (**this presentation**)
- Ångstrom coefficient can be determined using extinction profiles at various wavelengths (**future work**)

The Retrieval Method

Retrieval result:

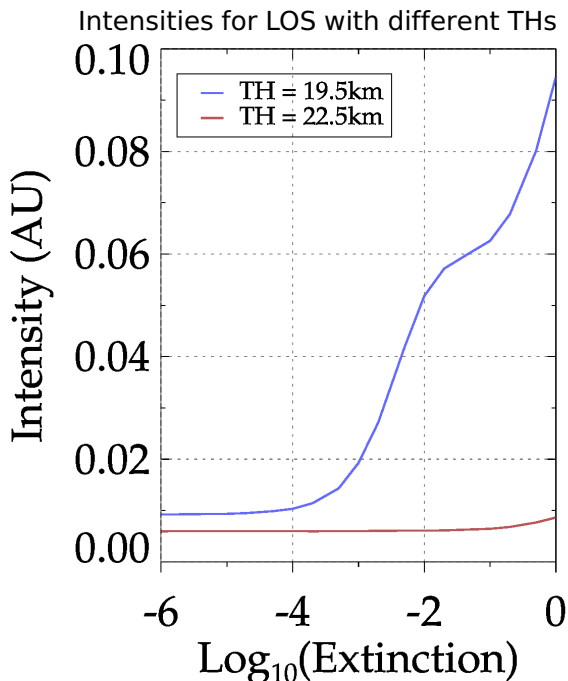
- Retrieve extinction profile from measured intensity profile (**this presentation**)
- Ångstrom coefficient can be determined using extinction profiles at various wavelengths (**future work**)

Assumptions/Approximations:

- Phase function is approximated by a Henyey-Greenstein function using a *known* asymmetry parameter
- Effective albedo below the lowest retrieval altitude is given by collocated nadir measurements
- Aerosol extinction at a specific layer does not affect the layers above

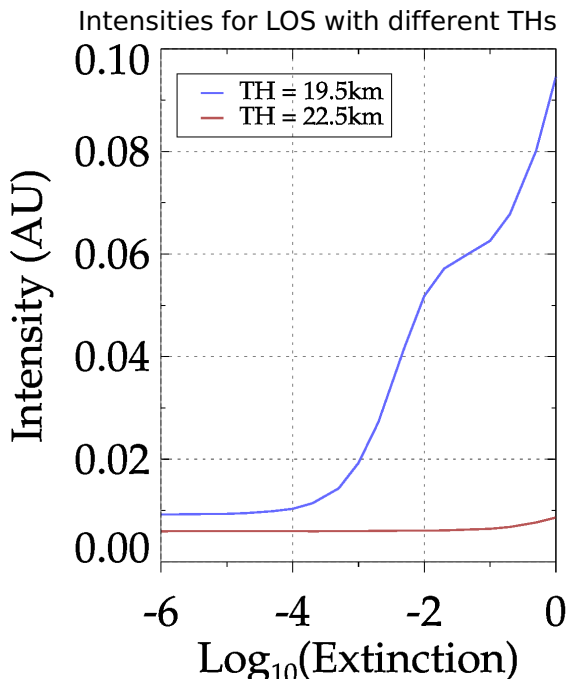
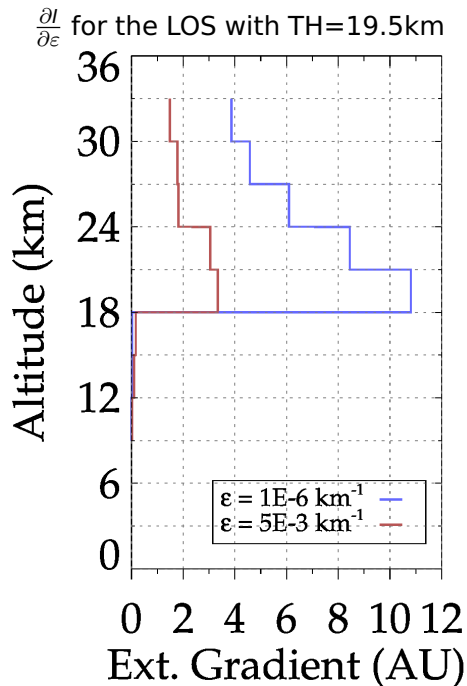
Bottom-Up Influence of Aerosol Extinction

SZA=30° SRAA=60° WV=750 nm Extinction Box Profile at 18 to 21 km



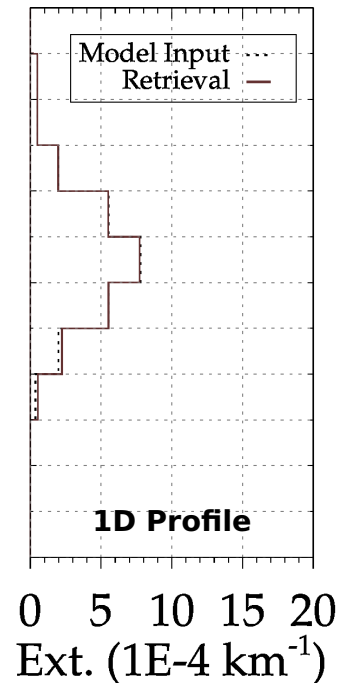
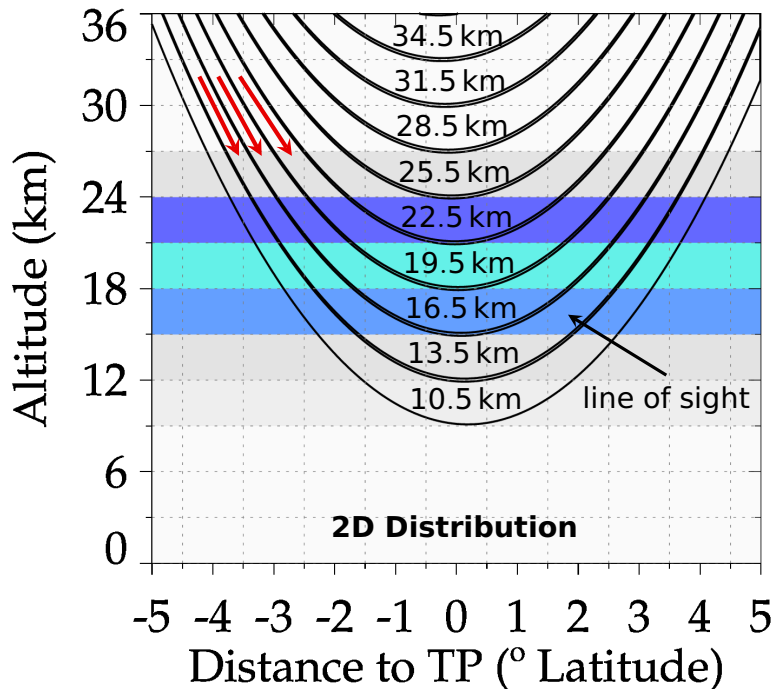
Bottom-Up Influence of Aerosol Extinction

SZA=30° SRAA=60° WV=750 nm Extinction Box Profile at 18 to 21 km



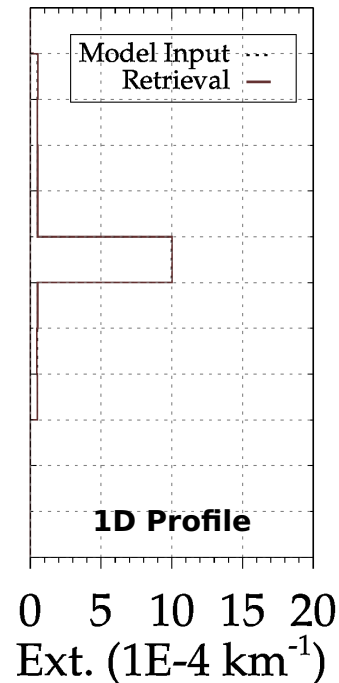
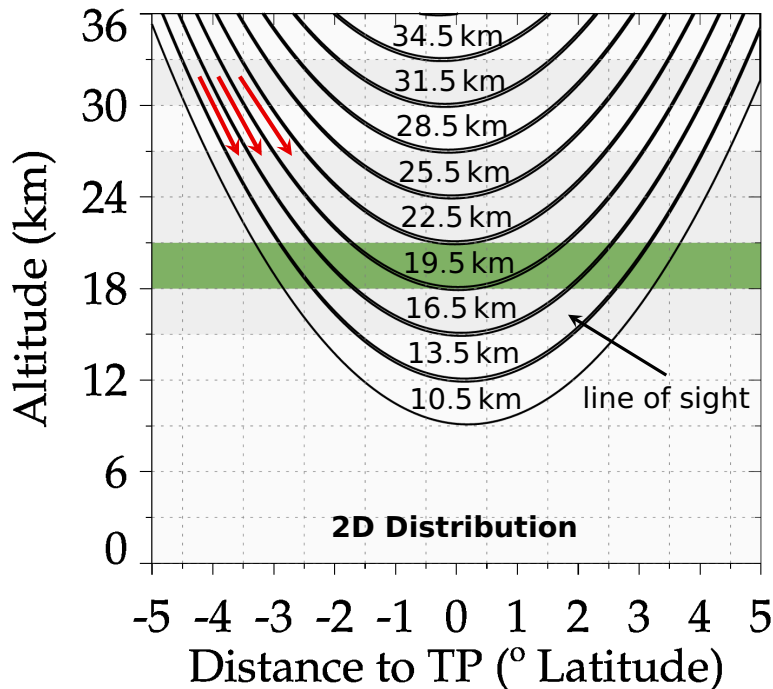
Self-Validation Tests

SZA=30° SRAA=60° WV=750 nm Gaussian Shaped Profile



Self-Validation Tests

SZA=30° SRAA=60° WV=750 nm Box Shaped Profile



Summary: Onion Peeling Method

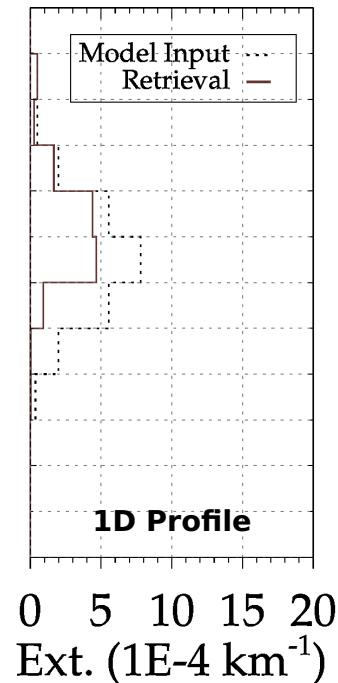
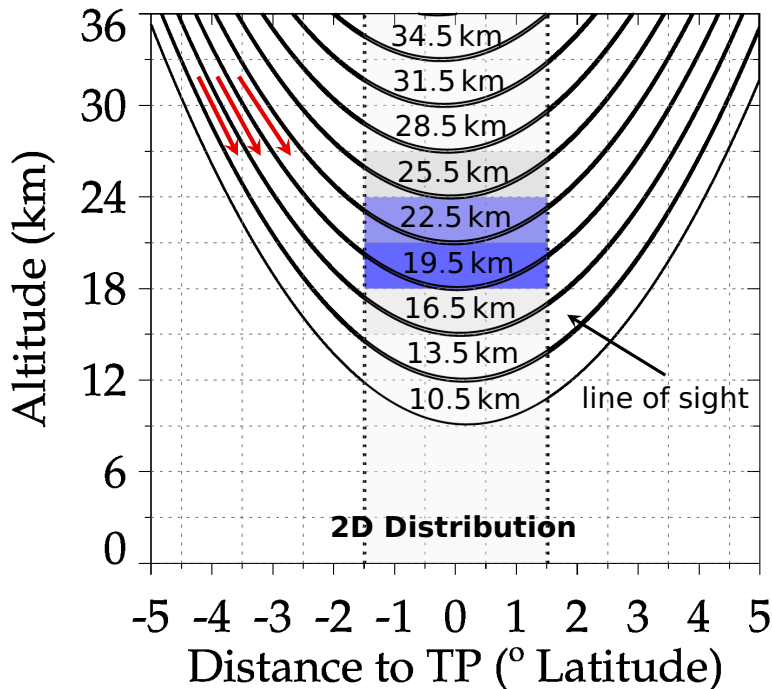
- The retrieval is able to retrieve the correct extinction profiles from simulated intensities. (Difference between model input and retrieval output less than 5 %, not varying with viewing geometry)
 - The lower boundary of the applicability of the retrieval is about 10 to 13 km. (Changing with wavelength and viewing geometry)
- ⇒ with this method the extinction profile between 13 and 30 km can be retrieved.

Horizontally Inhomogeneous Distributions

- Intensity profiles were simulated for different horizontal distributions.
- Results will be shown for running the retrieval with two approaches:
 - ▶ horizontal homogeneity (**current retrieval version**)
 - ▶ correct horizontal distribution

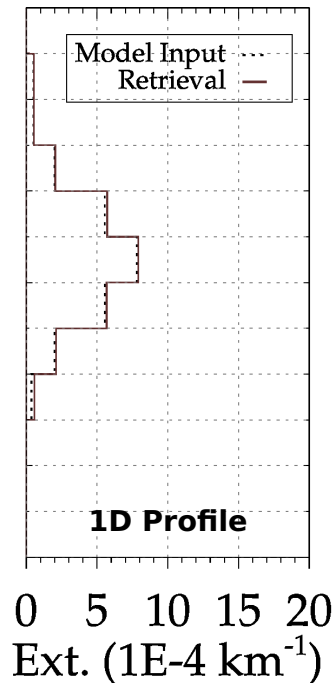
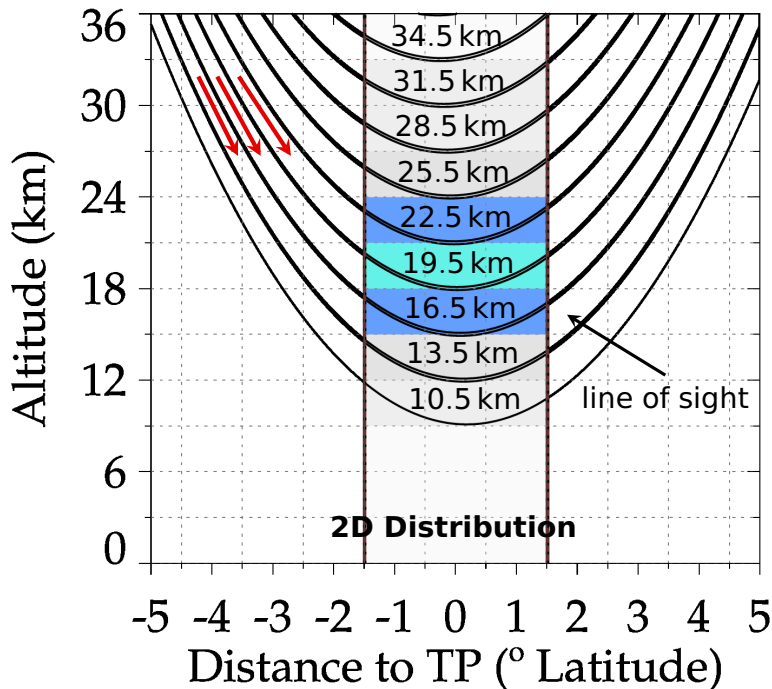
Horizontal Inhomogeneous Distributions

SZA=30° SRAA=60° WV=750 nm **Symmetric, Homogeneous Approach**



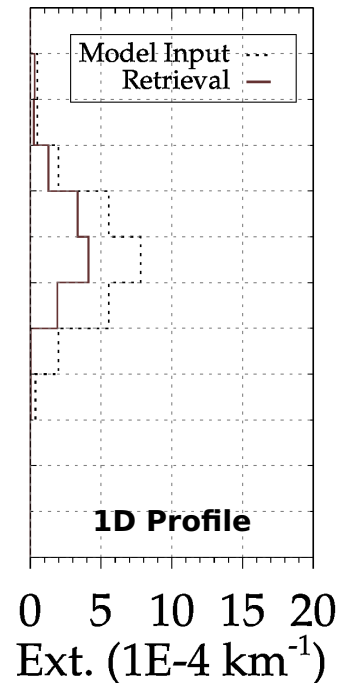
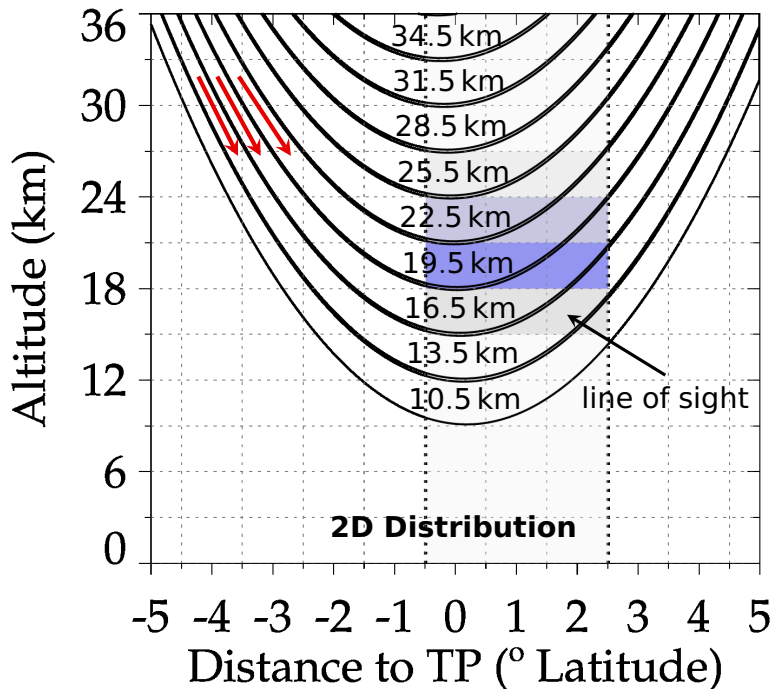
Horizontal Inhomogeneous Distributions

SZA=30° SRAA=60° WV=750 nm **Symmetric, Horiz. Distribution**



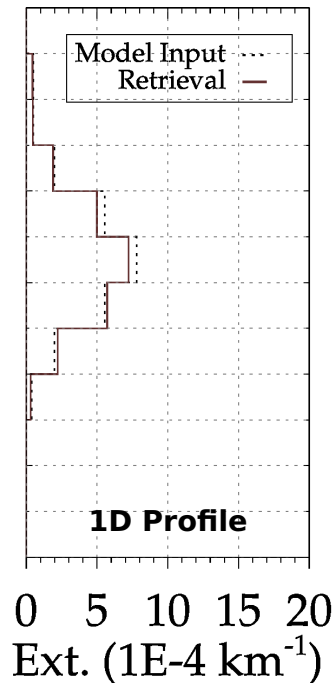
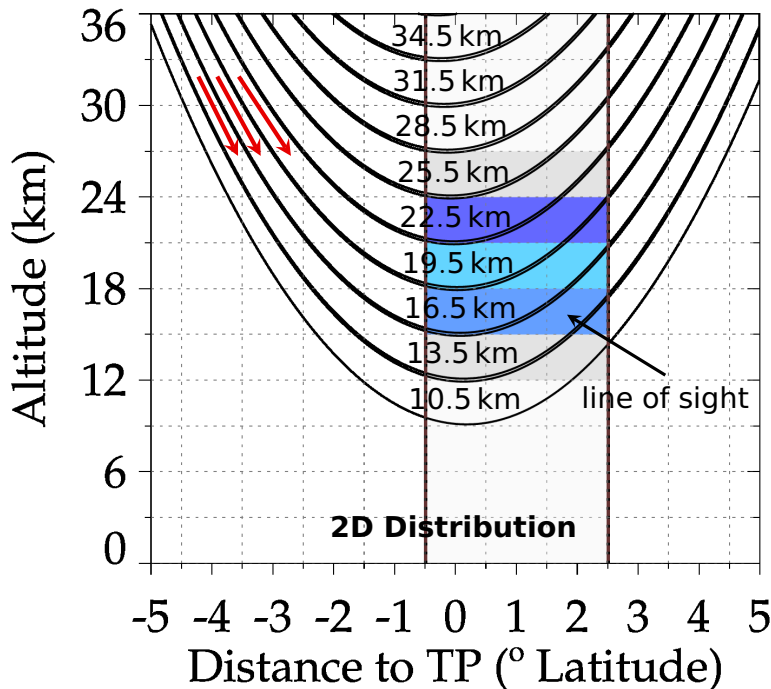
Horizontal Inhomogeneous Distributions

SZA=30° SRAA=60° WV=750 nm **Asymmetric, Homogeneous Approach**



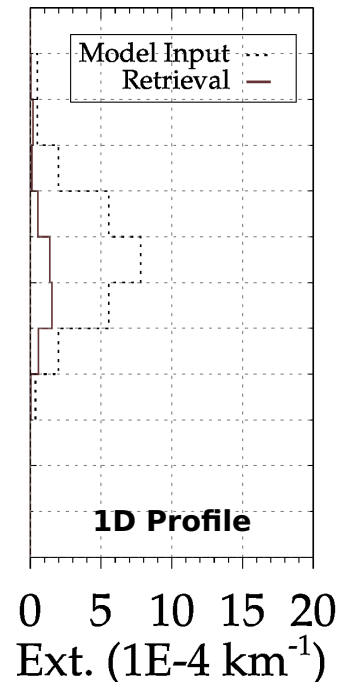
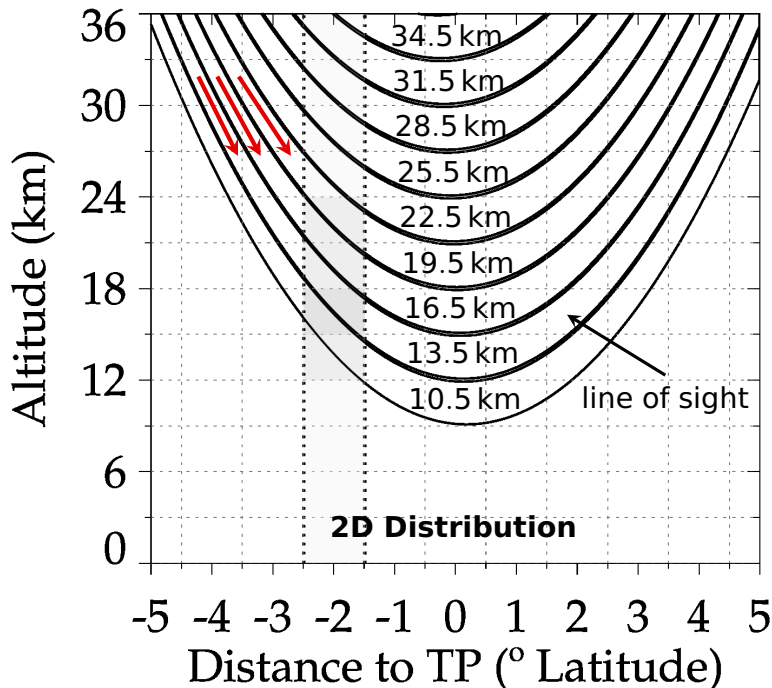
Horizontal Inhomogeneous Distributions

SZA=30° SRAA=60° WV=750 nm **Asymmetric, Horiz. Distribution**



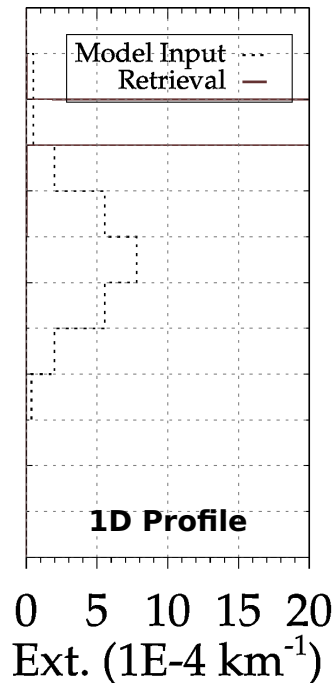
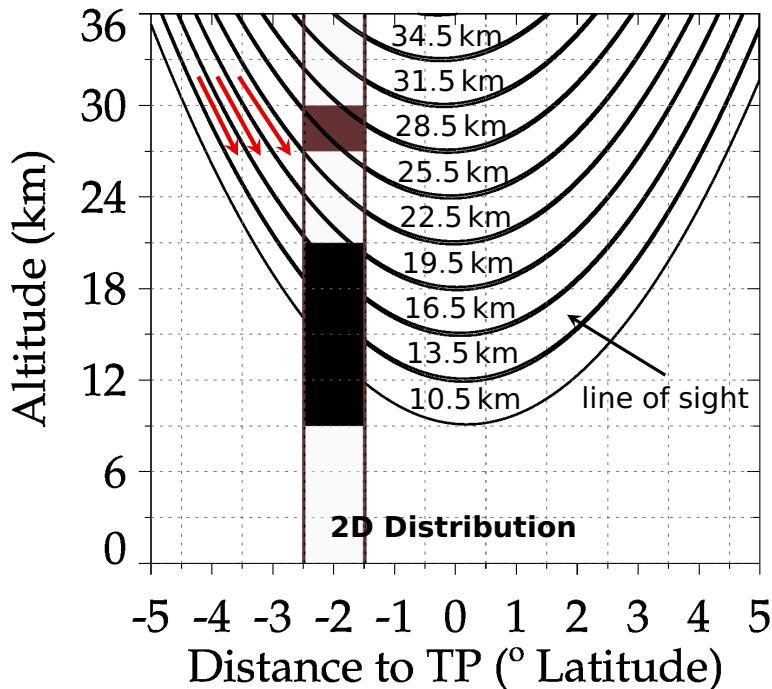
Horizontal Inhomogeneous Distributions

SZA=30° SRAA=60° WV=750 nm **Asymmetric Narrow, Homogeneous Approach**



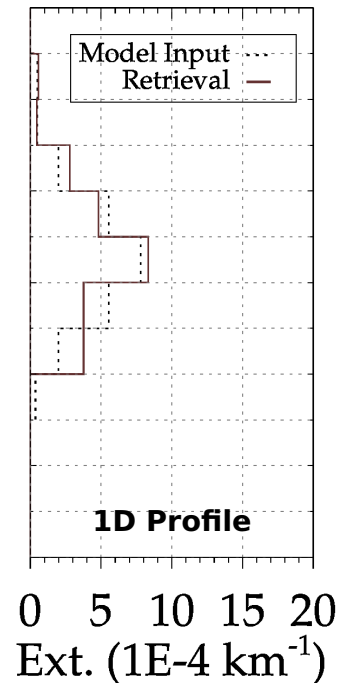
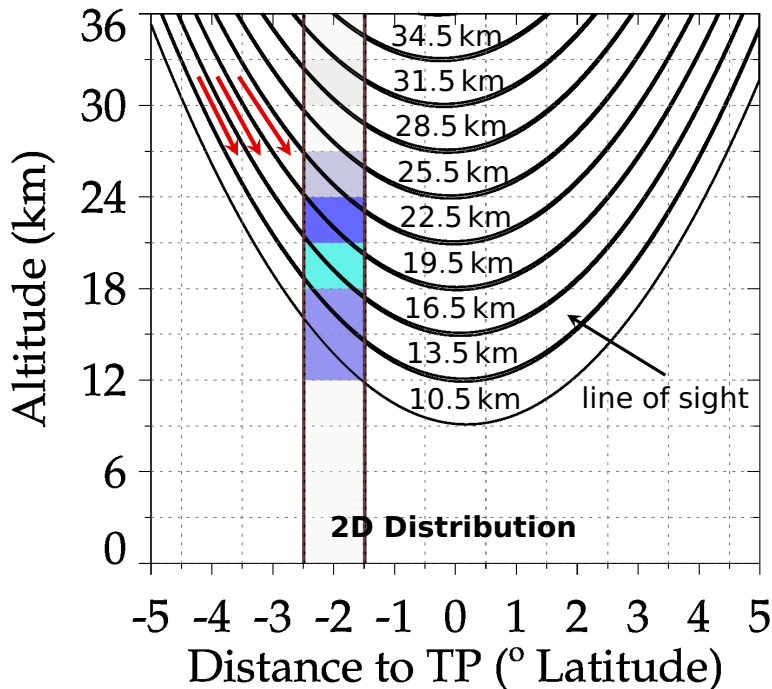
Horizontal Inhomogeneous Distributions

SZA=30° SRAA=60° WV=750 nm **Asymmetric Narrow, Horiz. Distribution**



Horizontal Inhomogeneous Distributions

SZA=30° SRAA=60° WV=750 nm **Asymmetric Narrow, Horiz. Distrib. and TH shifted**



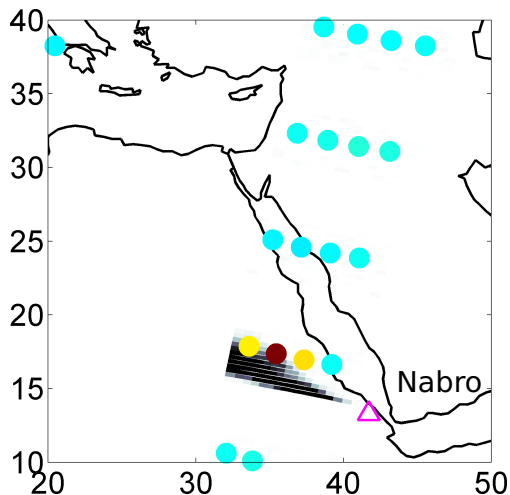
Case Study: Nabro Eruption 2011

- Investigation of the plume that originated from the first eruption on the 13th June 2011
- Aerosol Indices of SCIAMACHY, OMI and GOME-2 measurements in nadir geometry indicate H_2SO_4 droplets and negligible amounts of ash particles (Penning de Vries et al., in prep.)
- Phase function is approximated by a Henyey Greenstein function with an asymmetry parameter of 0.6, representing small aerosol droplets
- Retrieval is assuming a homogeneous layer

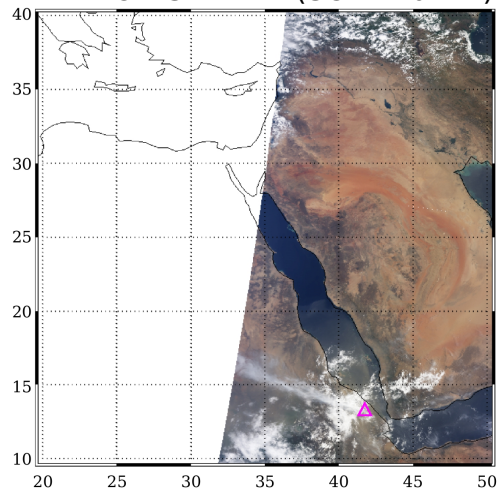
Case Study: Nabro Eruption 2011

13th June 2011 - About 12 hours after the eruption

- : Limb Color-Index at a tangent height of 18.5 km (tangent point coord.)
- : Nadir SO₂ column density



MODIS TERRA (SCIA -10min)



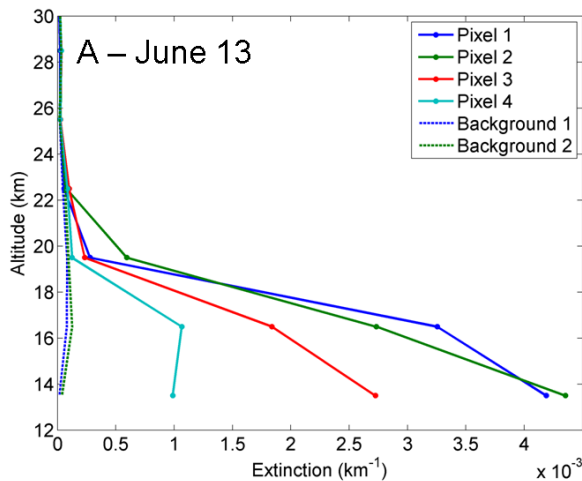
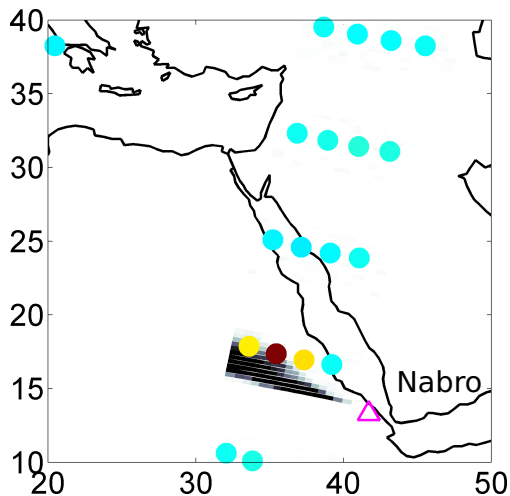
Source: Penning de Vries et al., in prep



Case Study: Nabro Eruption 2011

13th June 2011 - About 12 hours after the eruption

- : Limb Color-Index at a tangent height of 18.5 km (tangent point coord.)
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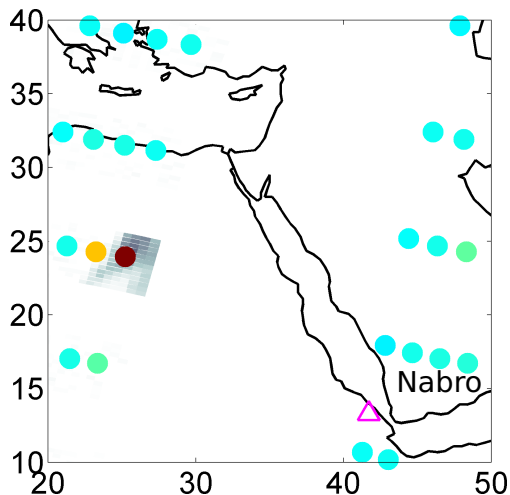


Source: Penning de Vries et al., in prep

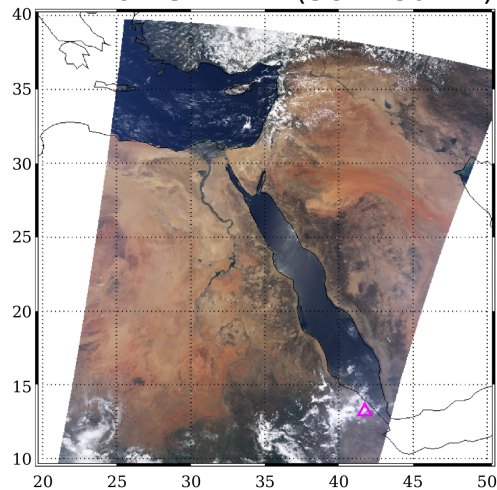
Case Study: Nabro Eruption 2011

14th June 2011 - About 36 hours after the eruption

- : Limb Color-Index at a tangent height of 18.5 km (tangent point coord.)
- : Nadir SO₂ column density



MODIS TERRA (SCIA -30min)



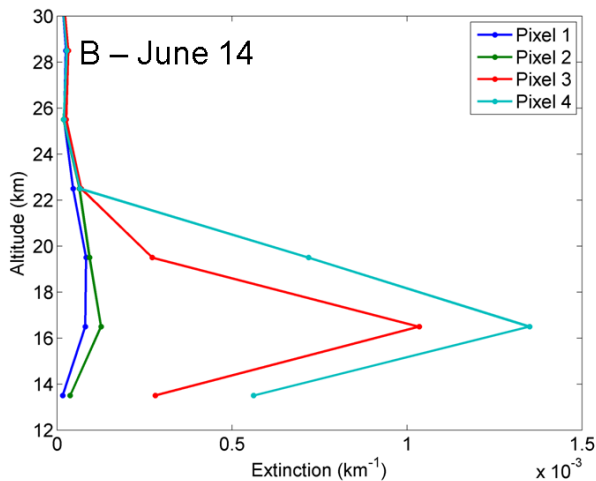
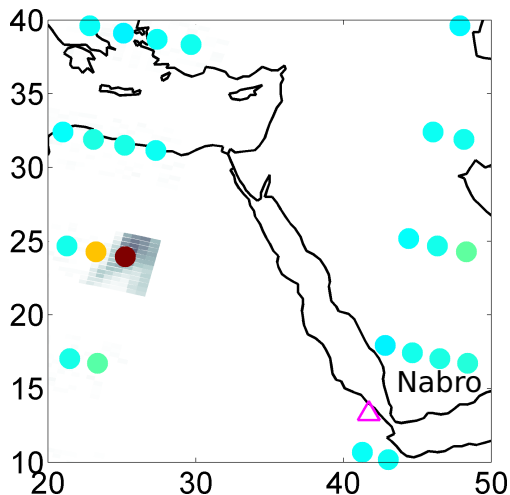
Source: Penning de Vries et al., in prep



Case Study: Nabro Eruption 2011

14th June 2011 - About 36 hours after the eruption

- : Limb Color-Index at a tangent height of 18.5 km (tangent point coord.)
- : Nadir SO₂ column density



Source: Penning de Vries et al., in prep

Summary

- Onion peeling approach is generally working
- Inhomogeneous aerosol layers have two major effects on a retrieval that assumes horizontal homogeneity:
 - ▶ Underestimation of the absolute extinction (\Rightarrow Aerosol optical depth)
 - ▶ Underestimation of the top height of an aerosol layer.
- Larger retrieval uncertainties for narrow inhomogeneous layers (e.g. volcanic plumes) with distances of more than 100 km to the tangent point

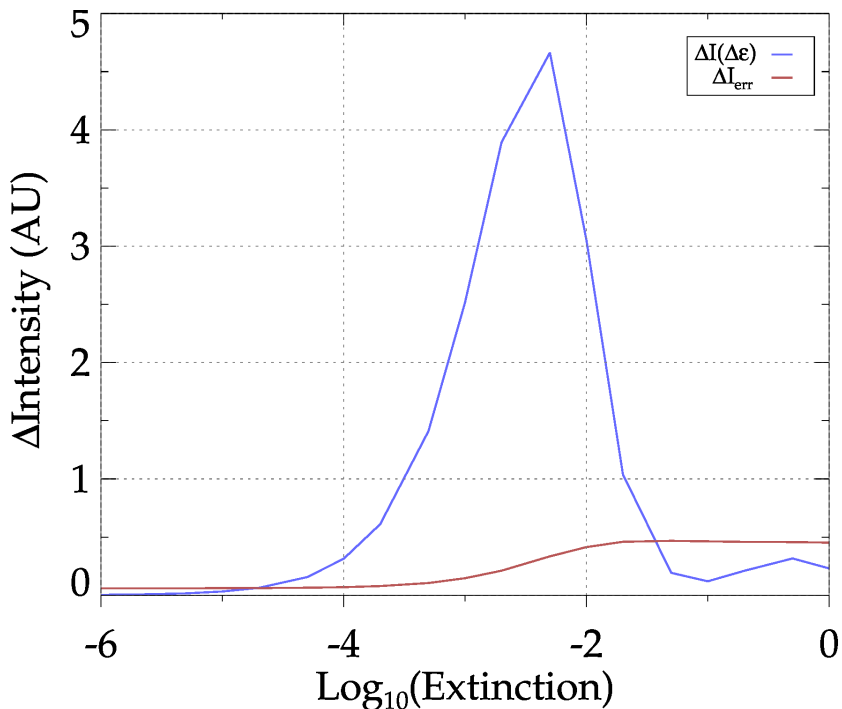
Thanks for your attention!

Thanks to Tim Deutschmann for his work and support on McArtim.

Questions are welcome!

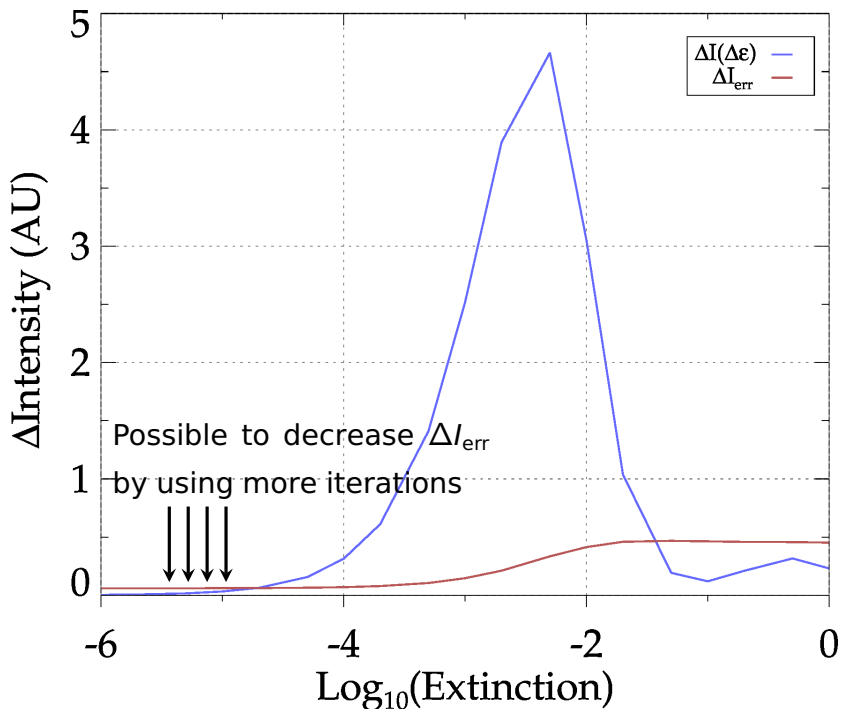
Retrieval Sensitivity Range

SZA=30° SRAA=60° WV=750 nm Extinction Box Profile at 18 to 21 km Albedo = 1.0



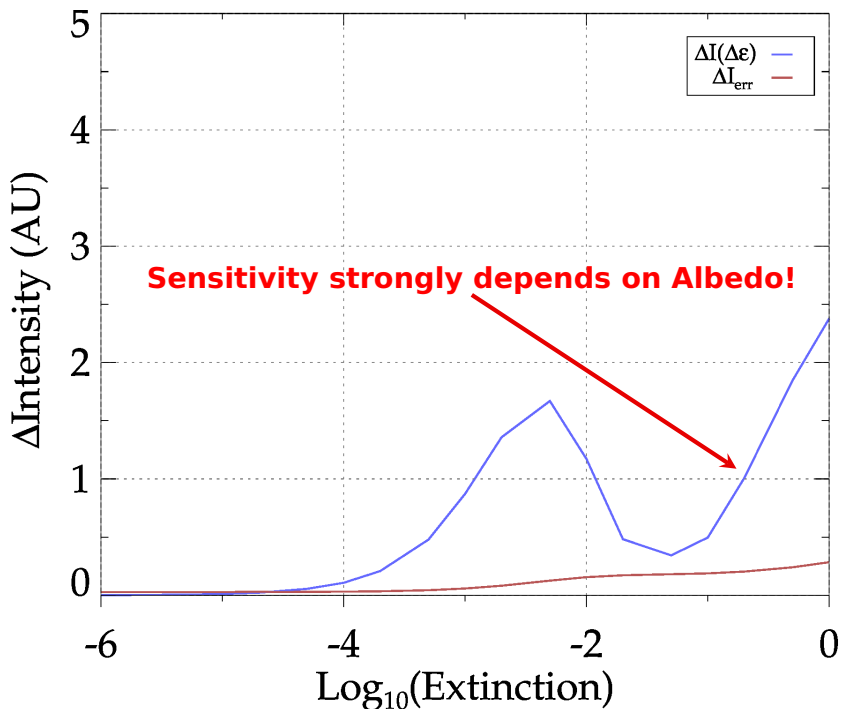
Retrieval Sensitivity Range

SZA=30° SRAA=60° WV=750 nm Extinction Box Profile at 18 to 21 km Albedo = 1.0



Retrieval Sensitivity Range

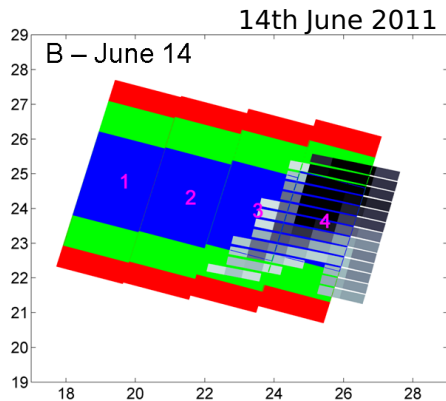
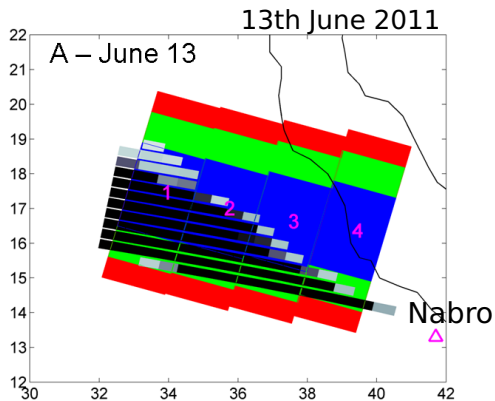
SZA=30° SRAA=60° WV=750 nm Extinction Box Profile at 18 to 21 km Albedo = 0.2



Example for Horizontal Inhomogeneity

Different limb LOS at an altitude of 19.5 km

- : LOS with TH = 19.5 km
- : LOS with TH = 16.5 km
- : LOS with TH = 13.5 km
- : Nadir SO₂ column density



Source: Penning de Vries et al., in prep