Retrieval of stratospheric aerosol parameters from SCIAMACHY limb measurements

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Outline

- 2 Algorithms investigated/developed:
  1. Retrieval of the aerosol extinction coefficients
     - Improvements/bug fixes
     - Studies on effects of clouds and assumed particle size
  2. Aerosol particle number density and size distribution retrieval
- Conclusions and outlook

Retrieval of the aerosol extinction coefficients

Extinction coefficients V1.3: optimized initialization

V1.1 & 1.3 common features:

- Color ratio 750/470 nm
- Reference tangent height ~35 km
- Phase functions from Mie calculations

V1.1:

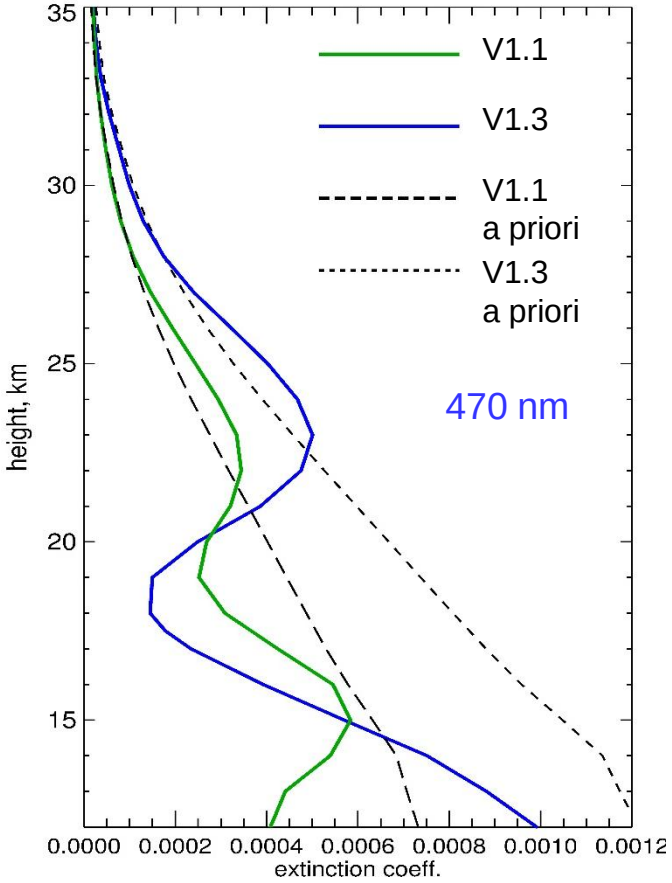
- Extinction coefficients from ECSTRA at 800 nm and from LOWTRAN at 470 nm
- Resulting Angstrom coefficient: 1.55

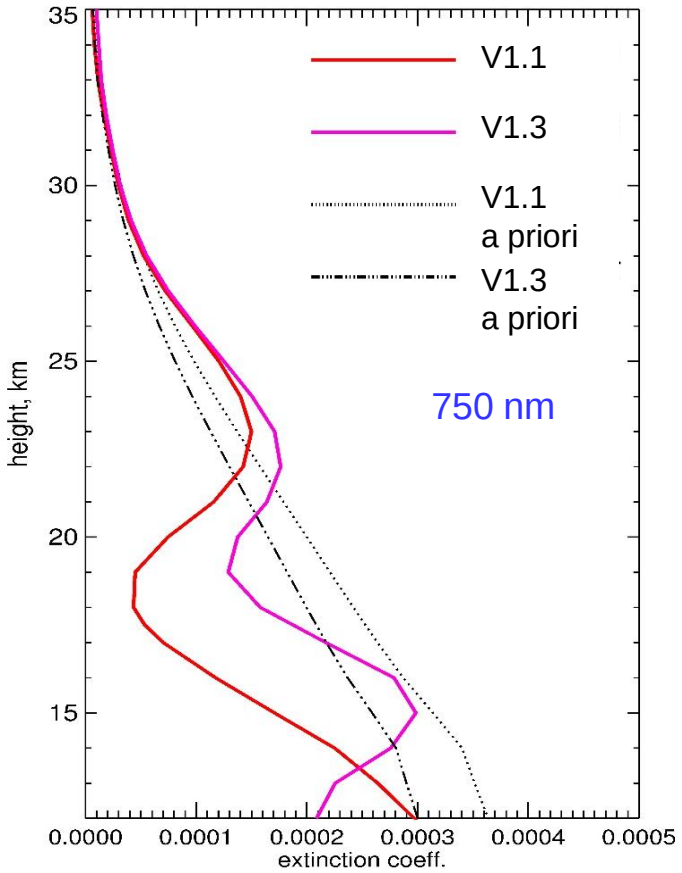
V1.3:

- Extinction coefficients from Mie calculations
- Resulting Angstrom coefficient: 2.58

V1.1 – the standard retrieval version (Ernst et al., 2012)
V1.3 and V1.4 (next slide) – retrievals optimized in this study

Aerosol extinction coefficient profiles in tropics (15.07.2008)





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Extinction coefficients V1.4: Single wavelength retrieval

V1.4:

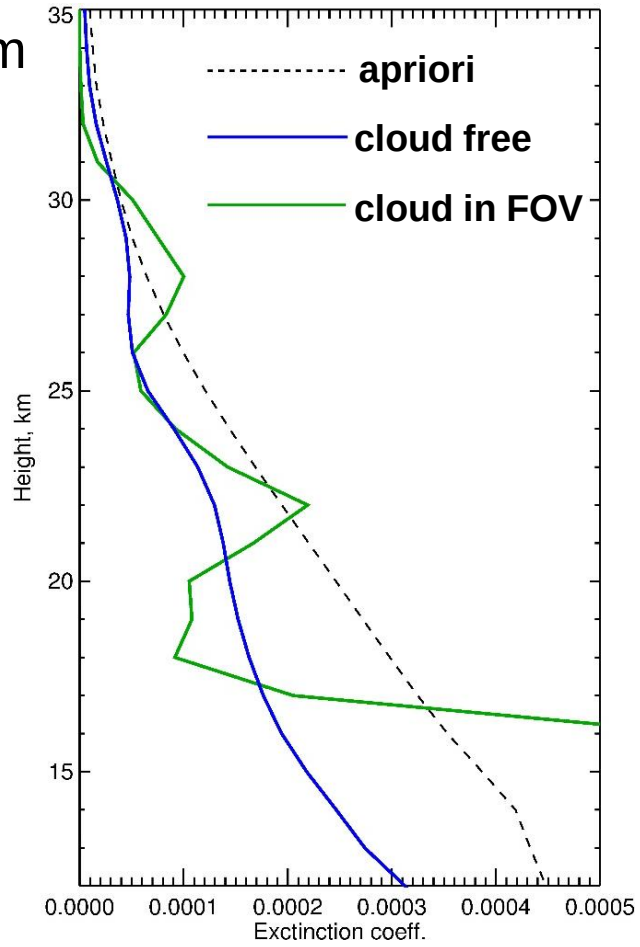
- Retrieval without a color ratio approach
  - Extinctions at all wavelengths are retrieved independently
- Expected advantage: reduces error budget by avoiding influence of errors at 470 nm
- 470 nm is less sensitive to aerosols =>
  not to be used in the single wavelength retrieval

Issue with “cloudy” profiles

Major issues:

- Oscillations if a cloud in FOV, i.e., above ~ 7km
- Possible solution:
  - exclude all THs at or below the cloud

Cloudy vs. cloud free



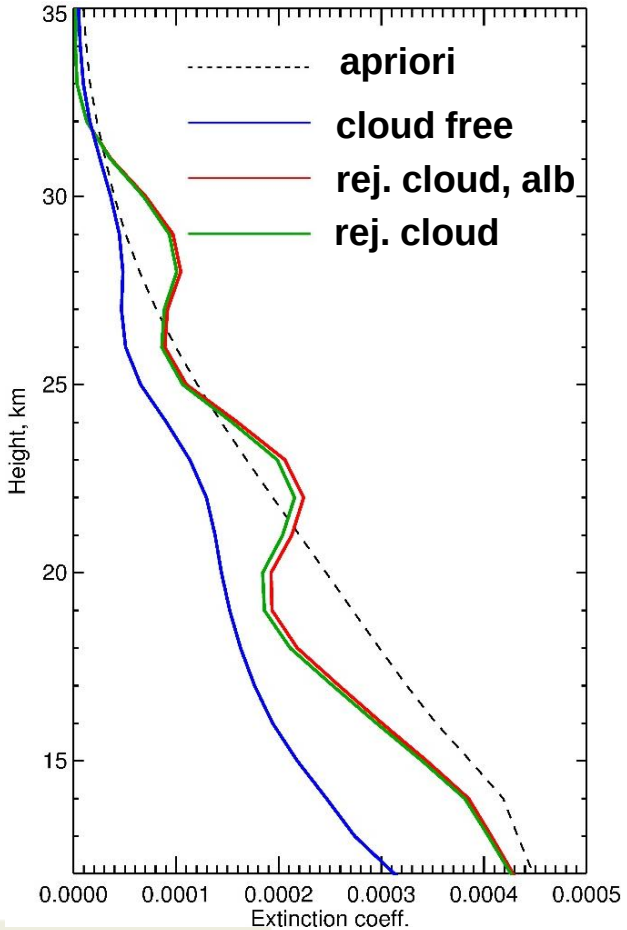
	Cloud at 15 km	Cloud free
Orbit	6674	6681
Date	10/6/2003	10/6/2003
Lat	4.54 N	2.42 N
Long	25.52 E	27.15 W

Issue with “cloudy” profiles

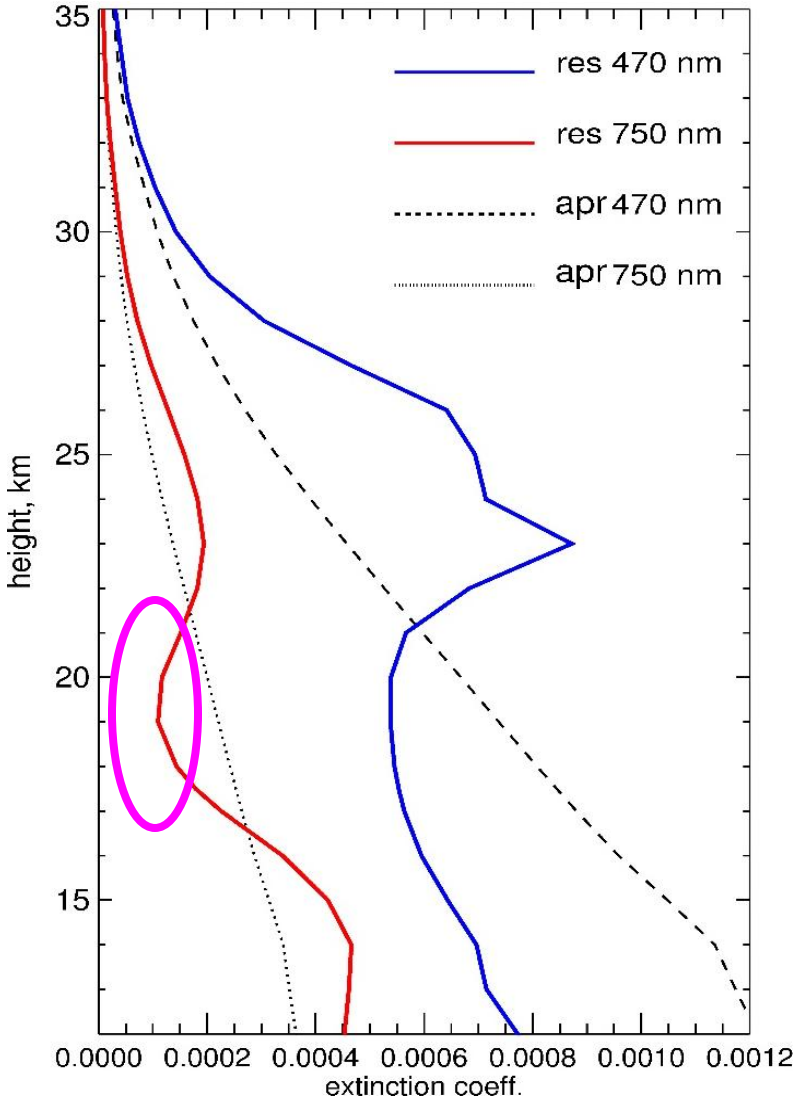
Major issues:

- Oscillations if a cloud in FOV
- Possible solution:
  - exclude all THs at or below the cloud
- Apparent high bias if the “cloudy” TH is rejected
- Possible solution:
  - Fit for the surface albedo
  - does not affect the bias
- Conclusion:
  - no solution for high clouds so far
- Workaround:
  - work with cloud free profiles only

Can albedo fit help?



A feature around 20 km



Feature around 20 km:

- Typical for tropics in July => where does it come from?
- Unlikely due to variations in number density profile
- Possibly related to difference in PSD (this assumption is evaluated at the next slides)

A feature around 20 km

- Wrong particle size can produce errors and features!
- Manual spectral fit to estimate PSD parameters:

Blue: pure Rayleigh scattering

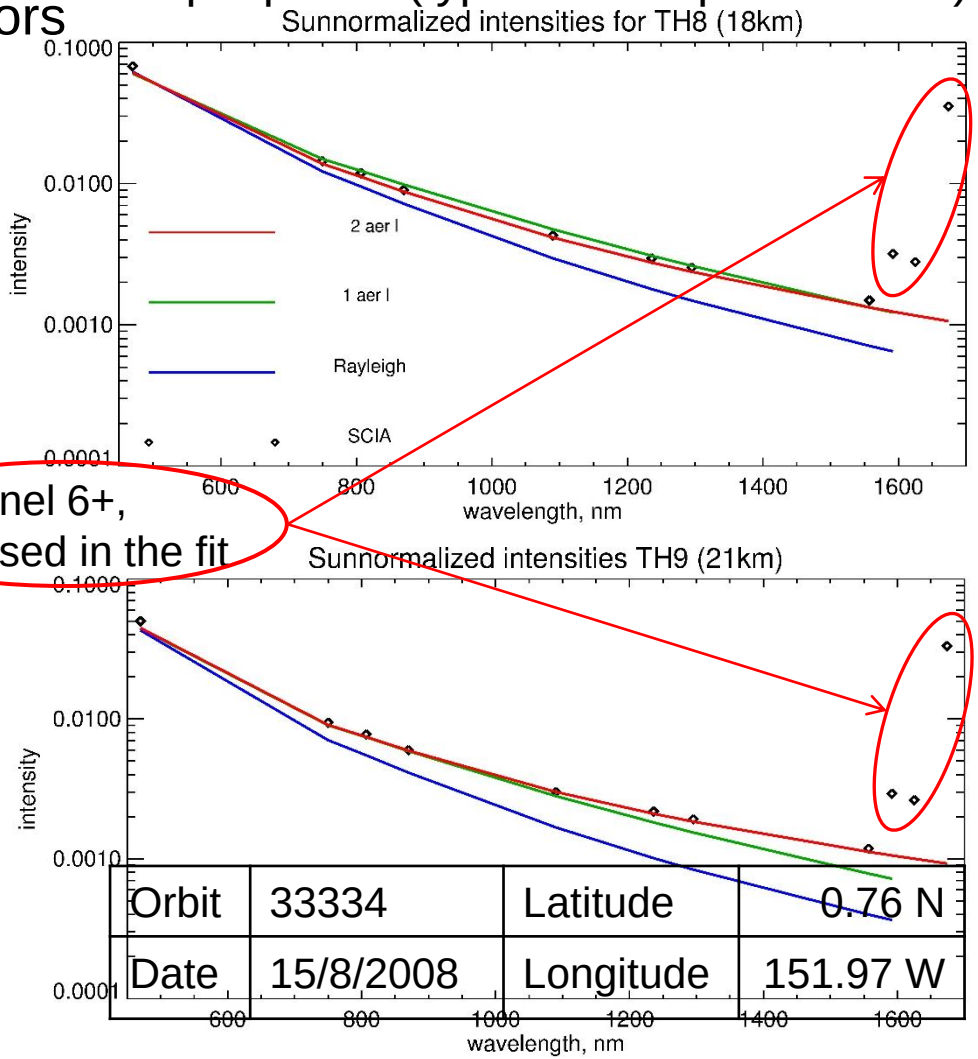
Green: standard settings (one aerosol layer):

Height, km	Mod. R, μm	σ
12-46	0.11	1.37

Red: manually fitted aerosol PSD parameters (two layers):

Height, km	Mod. R, μm	σ
12-20	0.06	1.6
20-46	0.07	1.9

Example profile (typical for tropics in 2008)

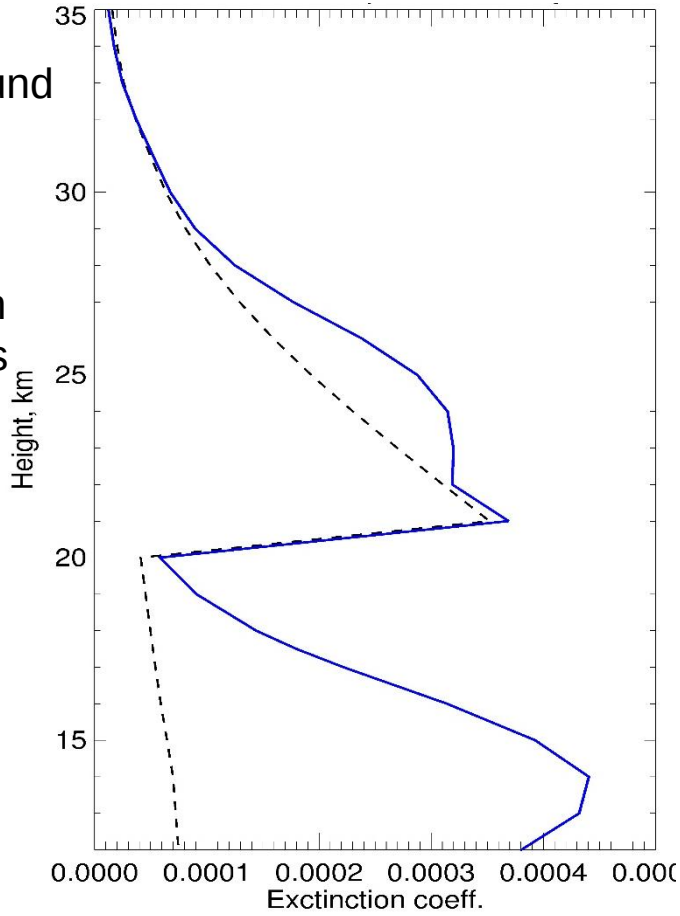


Retrieval results using fitted PSD parameter

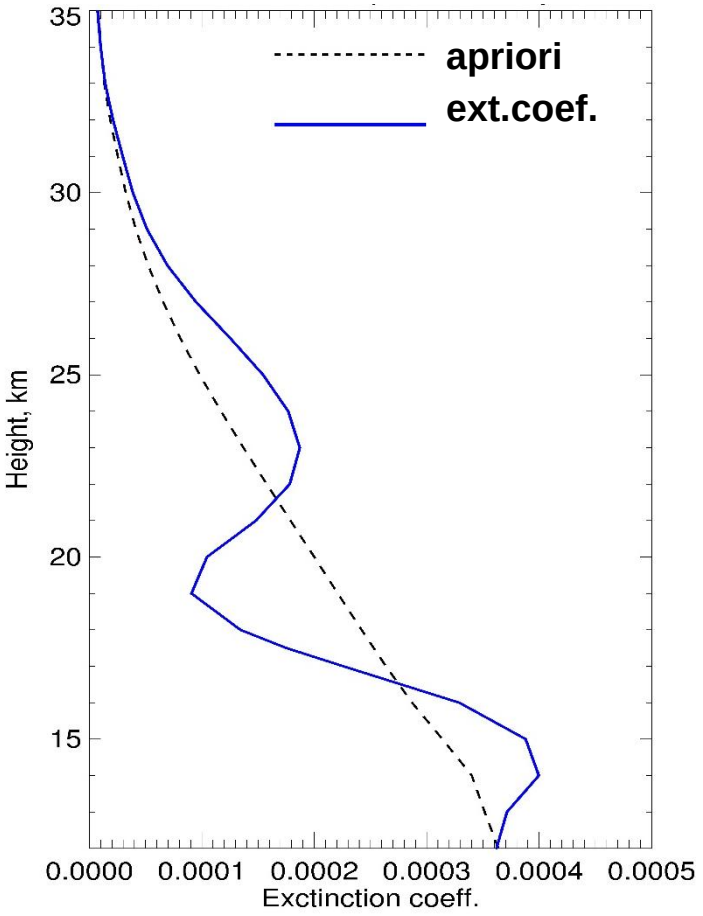
Key findings:

- A priori extinction coefficient profile calculated based on the fitted PDS parameters reproduces the feature around 20 km
- The fit results does not deviate significantly from a priori in the altitude range in question => the initial guess already describes the observation very well.
- The resulting profile is similar to that obtained with V1.4 retrieval.
- Conclusion: the observed feature could be caused by the change in aerosol PSD
- Unknown aerosol PSD produces large errors!

V1.4 retrieval with manually fitted PSD parameters



V1.4 retrieval with "standard" PSD parameters



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Aerosol particle size distribution retrieval

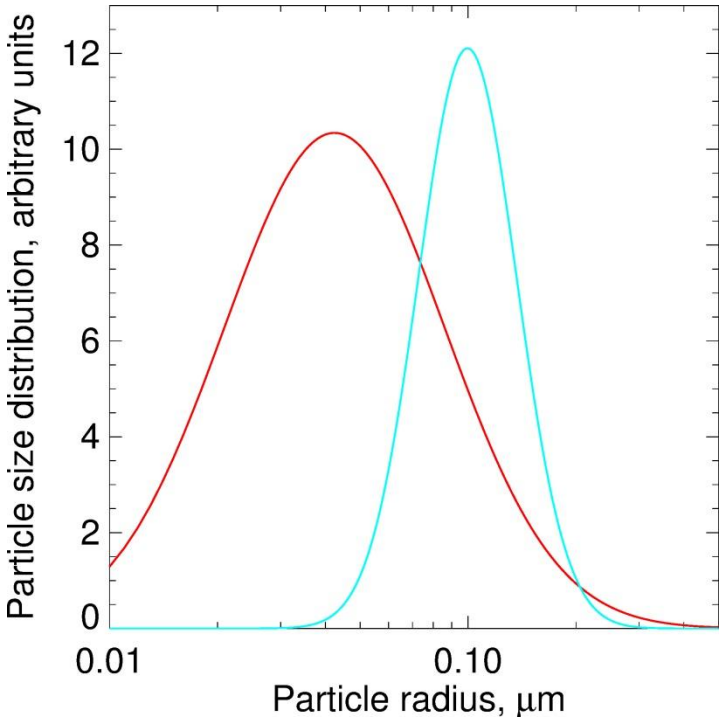
Retrieval parameters

Target parameters:

- Aerosol particle number density, N
- Mode radius of the aerosol particle size distribution, r_{mod}, (log-normal distribution is assumed)
- Standard deviation of the aerosol particle size distribution, σ, (log-normal distribution is assumed)

Retrieval approach:

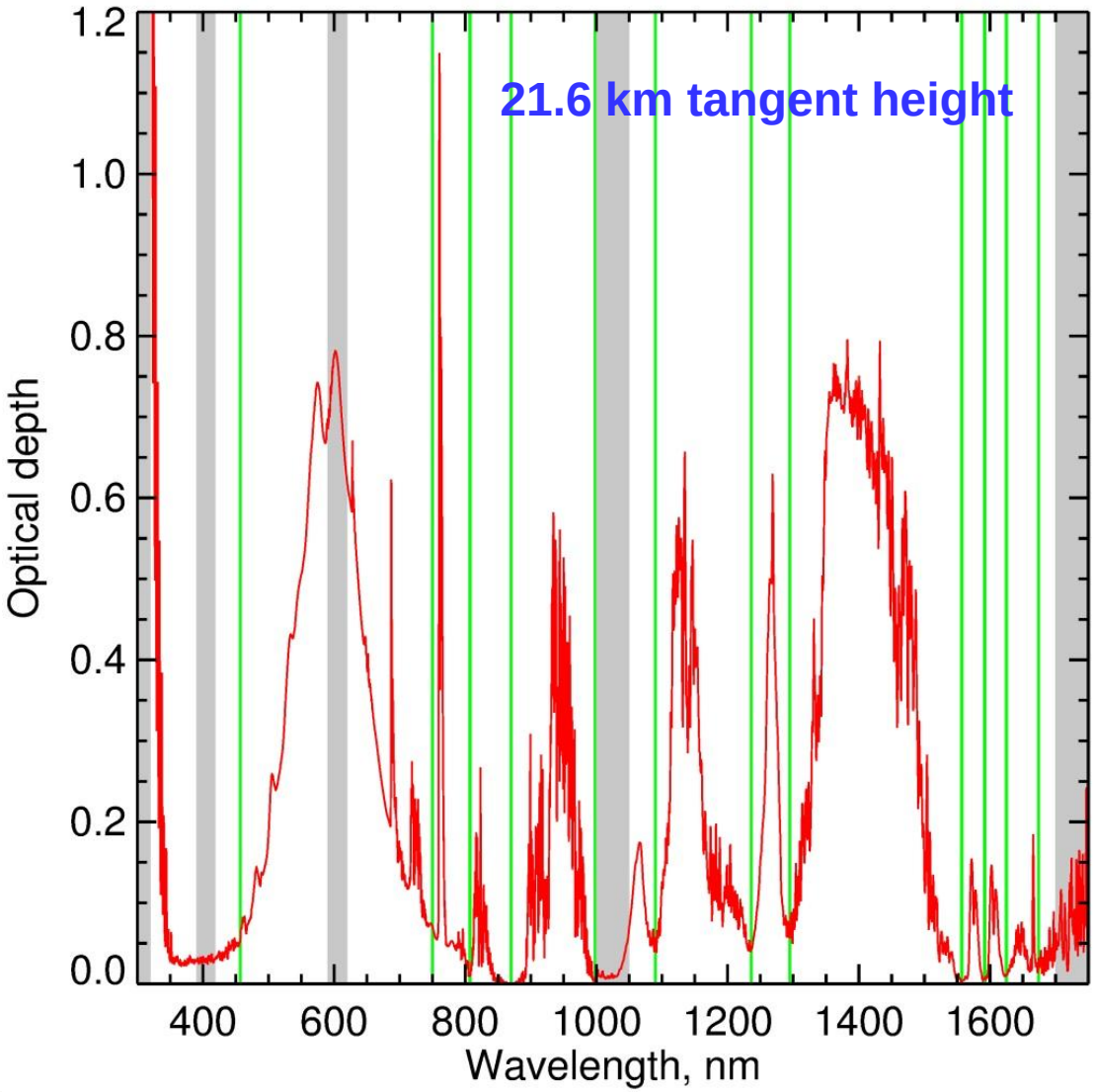
- Limb radiances at non-absorbing wavelengths
- Optimal estimation
- For now: simulation studies only



r_{mod} = 0.07 µm, σ = 2.03, Hess et al, 1998

r_{mod} = 0.11 µm, σ = 1.37, Deshler et al, 2008

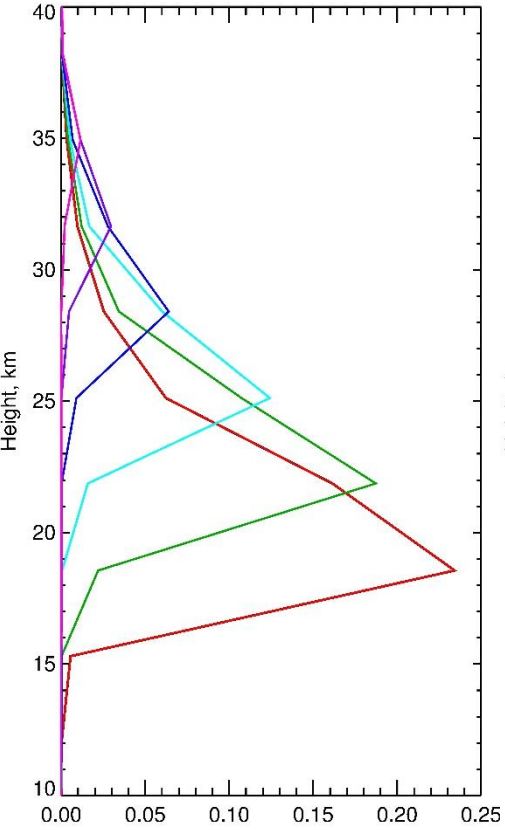
Spectral information to be used



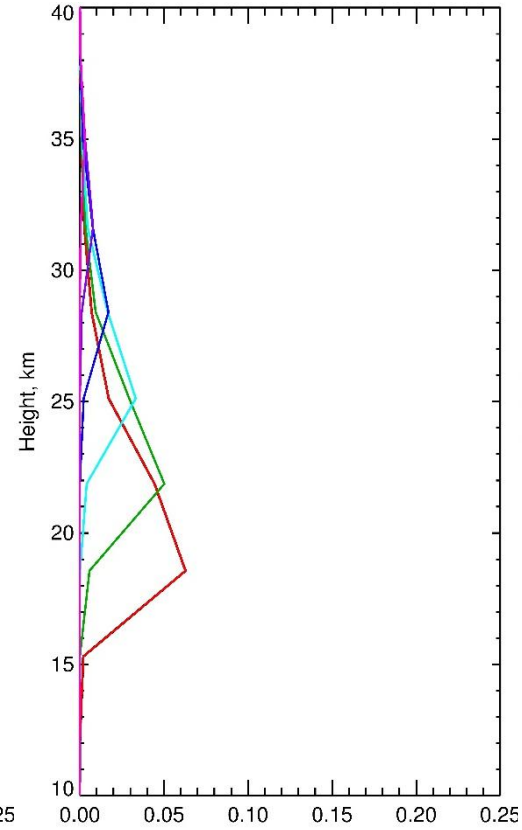
Non-absorbing wavelengths selected for the aerosol PSD retrieval: 750, 807, 870, 1080, 1236, 1295, 1557 nm.

Weighting functions

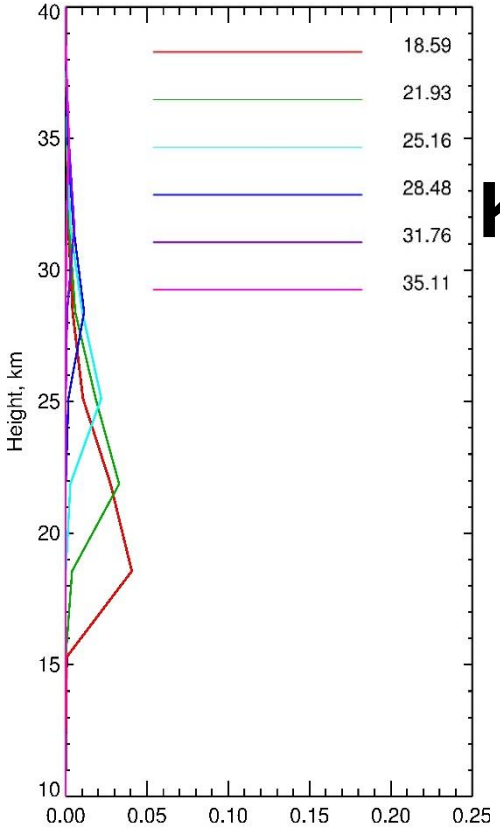
Mode radius



Distribution width



Number density



Weighting functions:

$$K = \left.\frac{\P F(x)}{\P x}\right|_{x=x_a}$$

F - radiative transfer operator

x – state vector with parameters to be retrieved

$x\downarrow a$ - a priori state

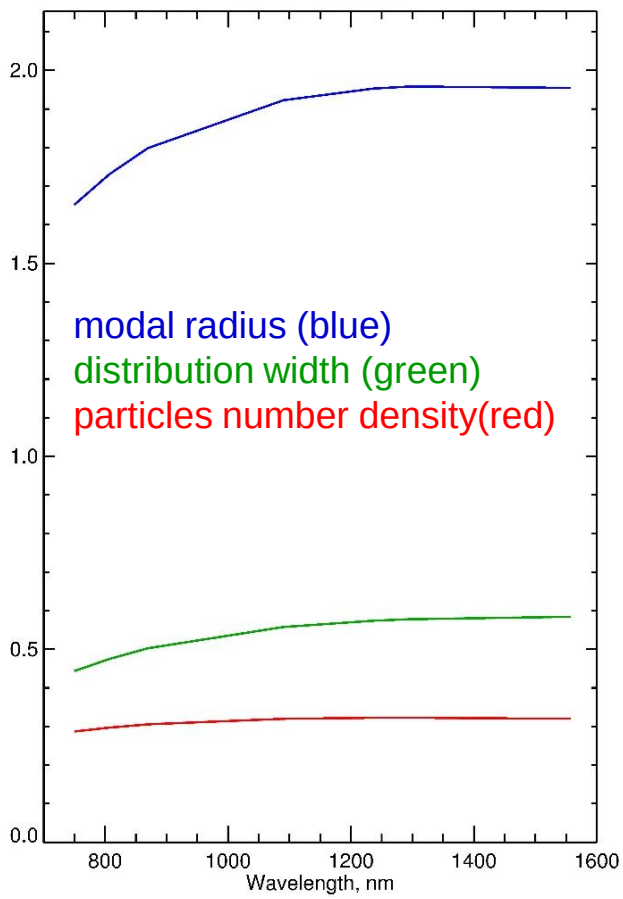
- Relative (logarithmic) WF for 750 nm (tropics)
- Weighting functions have similar shape for all latitude ranges
- Strongest sensitivity for the mode radius and weakest for the particle number density

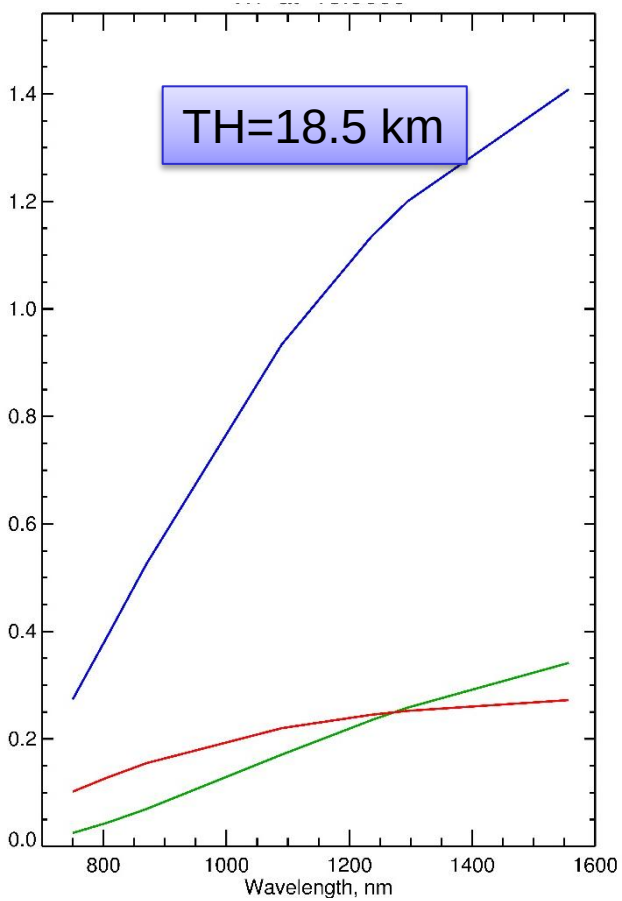
Weighting functions

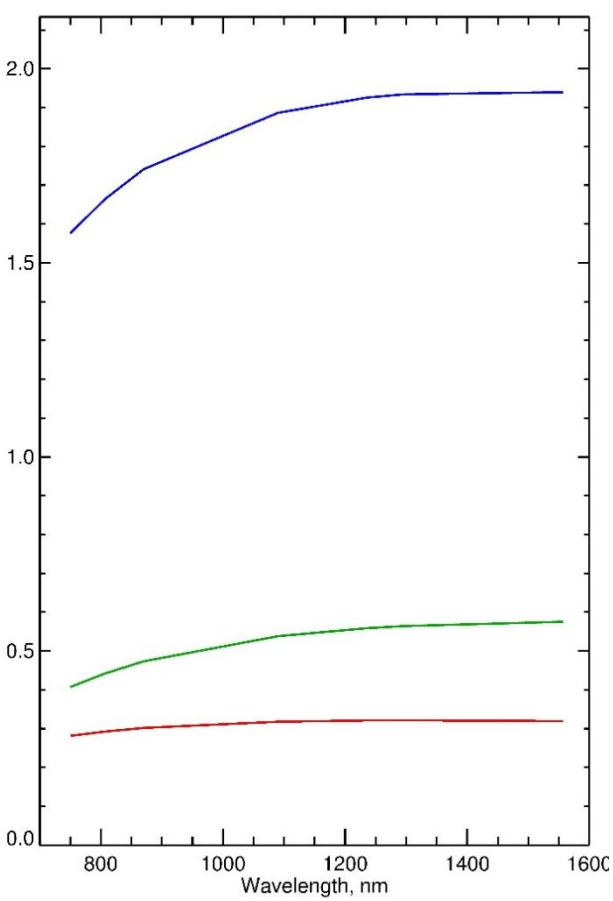
Tropics

Southern mid-latitudes

Northern high latitudes





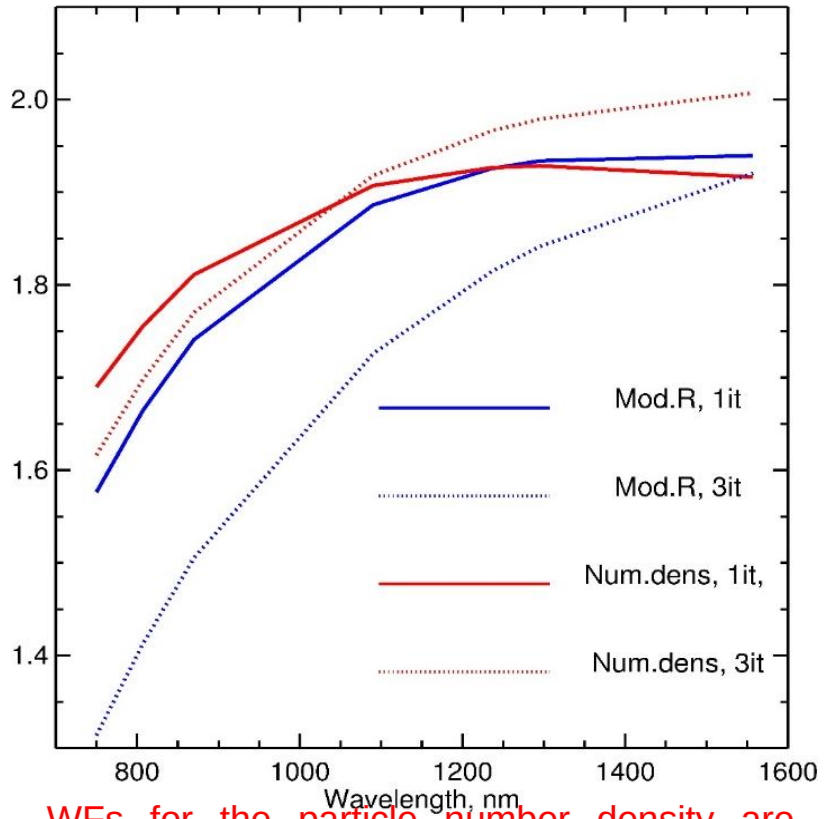


Often all three WFs don't provide a linearly independent basis => possible correlations

Initial approach: only the mode radius and particle number density will be retrieved.

Weighting Functions

Logarithmic weighting functions for the mode radius and particle number density at 18.5 km



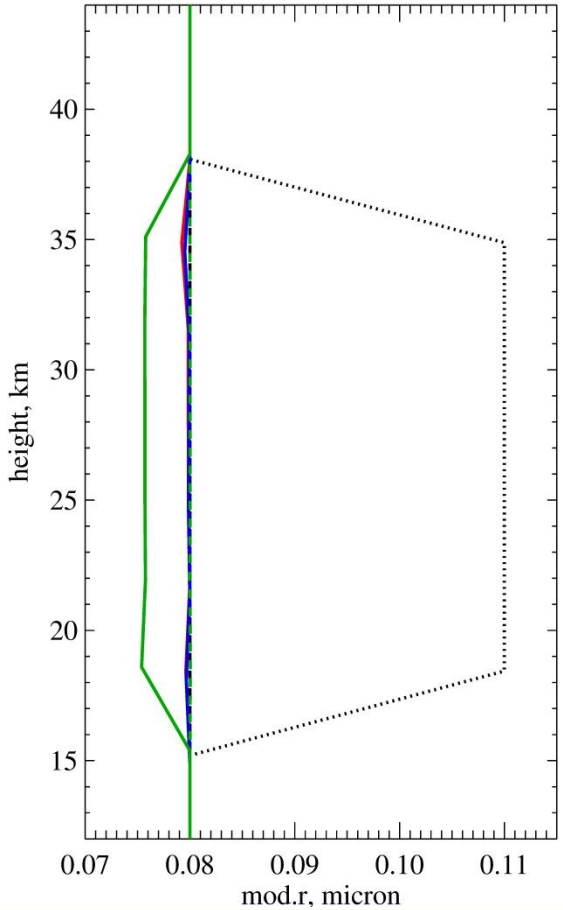
WFs for the particle number density are scaled to the factor 6

Issue: Exceptional situation at high Northern latitudes

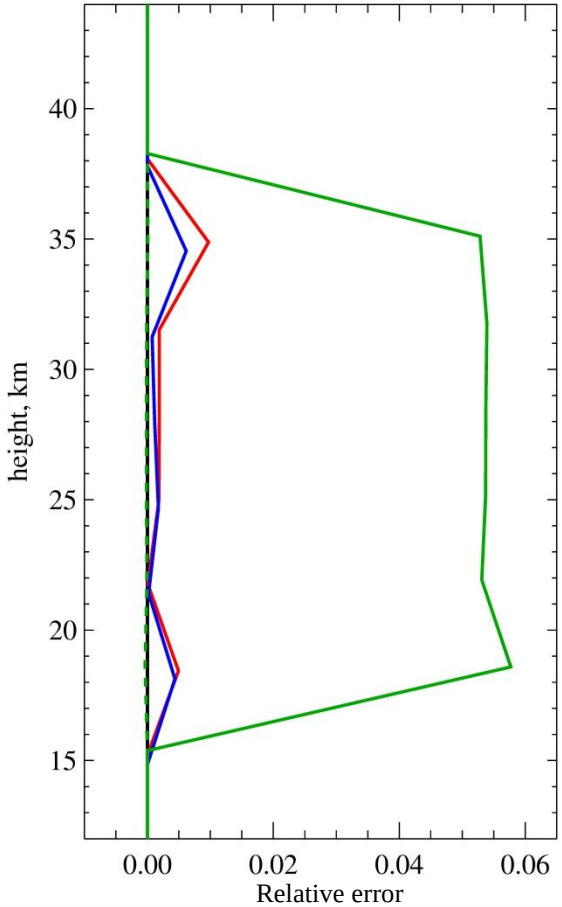
- Weighting functions for mode radius and for particle number density are well uncorrelated for the initial set of parameters => first non-linear iteration works well.
- At the updated set of parameters the weighting functions become more similar and correlation increases => iterative scheme diverge.
- Workaround: for the beginning only the mode radius will be retrieved at high northern latitudes.

Synthetic retrievals: Mode radius

A priori profile (dotted black) and the retrieval results (solid color)



Relative error of the retrieval



Parameter perturbations:

- Mode radius: 0.11 μ is the initial guess and 0.08 μ is the true value
- Number density: initial guess is obtained by increasing the true value by 40%.

Green: northern high latitudes, solid line -> perturbed particle number density, dashed line -> unperturbed particle number density

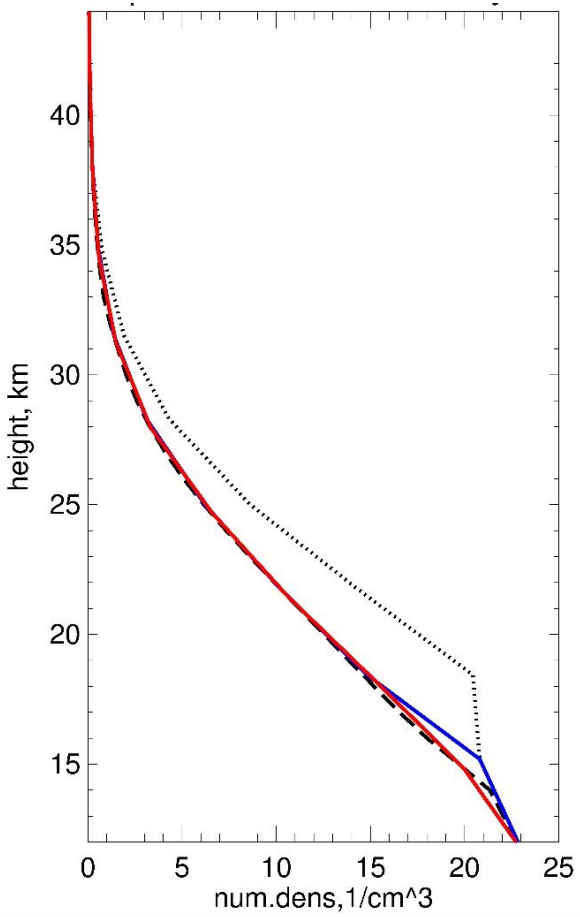
Blue: tropics

Red: southern mid-latitudes

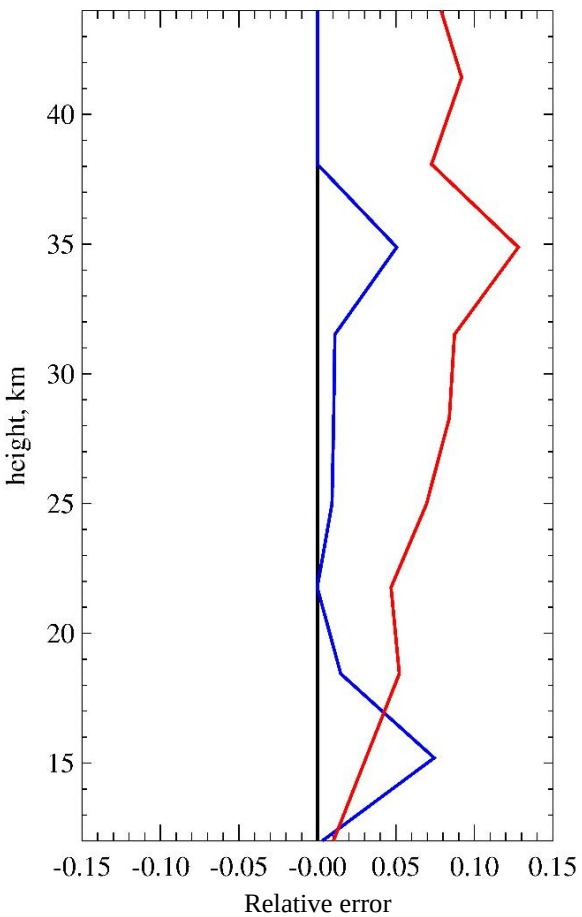
Retrieval of modal radius for all regions show very good results. Even with perturbed and not included into the retrieval particle number density at northern high latitudes an accuracy below 6% is achieved

Synthetic retrievals: Particle number density

A priori profile (dotted black) and the retrieval results (solid color)



Relative error of the retrieval



Parameter perturbations:

- Mode radius: 0.11 μ is the initial guess and 0.08 μ is the true value
- Number density: initial guess is obtained by increasing the true value by 40%.

Blue: tropics

Red: southern mid-latitudes

Retrieval of particles number density for the tropical region and southern mid-latitudes shows very good results. In the northern high latitudes the retrieval does not yet work well due to correlations in the weighting functions.

Conclusions and outlook

- Extinction coefficient retrieval:
  - Improvements over old version (1.1) by consistent initialization single wavelength retrieval
  - Retrieved profile depends strongly on prescribed particle size distribution profile
- Particle number density and size distribution retrieval:
  - First investigations on 3 parameter retrieval using limb spectra instead of single wavelengths
  - With the currently used wavelength range, at most, 2 parameters can be retrieved
  - A joint retrieval of the mode radius and particle number density shows good results for tropics and southern mid latitudes
  - Further investigations ongoing
  - So far, no investigations with real data have been performed yet

Prevailing Issues

- Clouds:
  - An apparent high bias in the extinction coefficient occurring when rejecting the cloudy tangent heights => further investigations ongoing.
- Measurement vector:
  - Both types of retrieval currently use TH normalized radiances to avoid calibration errors
  - Still leaves uncertainty due to darks and stray light
  - Main problem: Unknown aerosol density / properties at normalization altitude can generate huge errors in the profile
  - Possible solution: Use calibrated reflectances instead and retrieve albedo
- That requires very accurate radiances over a broad wavelength range!