3DCATS – WP 200: Impact assessment

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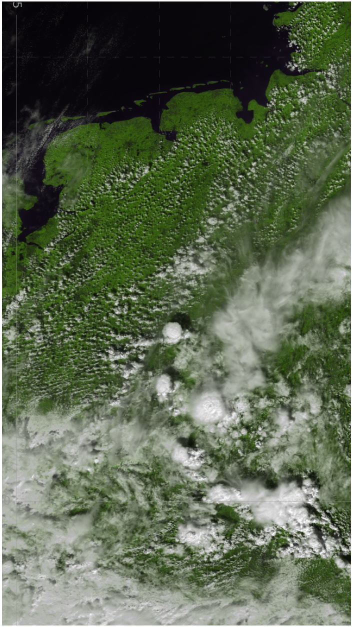
Introduction

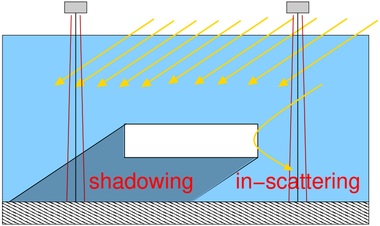
- Operational retrievals of tropospheric trace gases from space-borne instruments based on 1D radiative transfer neglect
  1. cloud scattering into clear regions
  2. cloud shadows
- Monte Carlo radiative transfer (MYSTIC-ALIS)
  ⇒ simulation of spectra for realistic 3D model atmospheres
- Application of NO_2 retrieval algorithm on simulated data:
  ⇒ estimation of retrieval error due to 3D cloud scattering



WP200 - Outline

- Aim: Generate synthetic data to test and improve NO_2 retrieval algorithm
- Retrieval test for one-dimensional geometry (clearsky and cloudy)
  - Status: finished
- 2D cloud scenario
  - Simulated spectra (1x1km^2 footprint) for 2D cloud case to investigate retrieval error dependence on various parameters
  - Status: ongoing, additional simulations see below
- LES cloud scenario
  - Cloud scene from ICON-LES model over Europe ($698 \times 763\,\mathrm{km}^2$)
  - All types of realistic clouds included
  - Various sun-satellite geometries and surface albedos
  - Generate synthetic dataset for geostationary orbit and Low Earth Orbit for VIS and O_2A-band
  - Status: finished
- Quantification of NO_2-retrieval error
  - Investigate impact of clouds on NO_2-retrieval using synthetic dataset
  - Status: ongoing, see WP300

Clearsky pixels in vicinity of clouds
Two base cases: low liquid water and high ice cloud



Sketch of step cloud setup.

Base case cloud settings

- cloud base at 2/9 km altitude
- cloud top at 3/10 km altitude
- cloud optical thickness: 10/5
- cloud droplet effective radius 10/30 μm
- optical properties from Mie / parameterization by Baum, Yang, Heymsfield

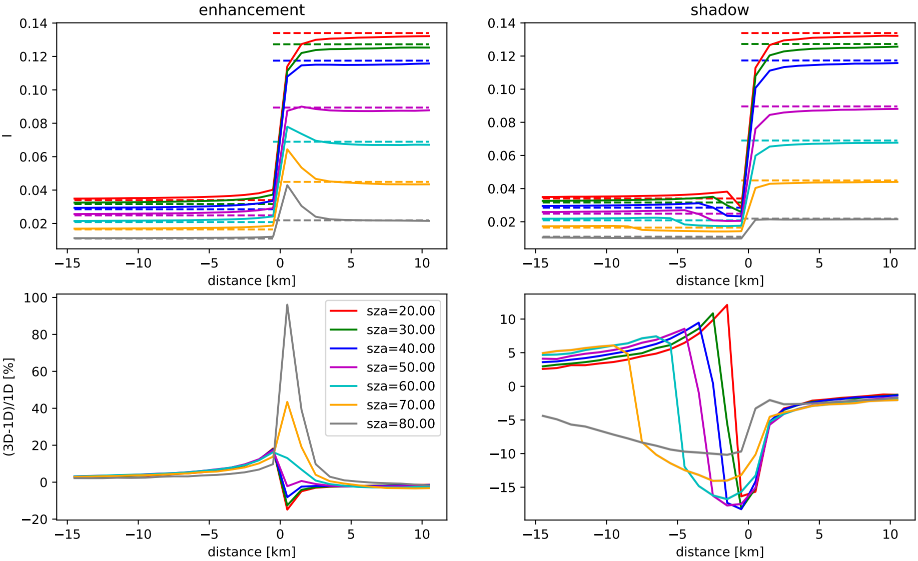
Geometry settings

- nadir observation geometry
- 1x1km^2 square field-of-view
- solar zenith angle: 50°

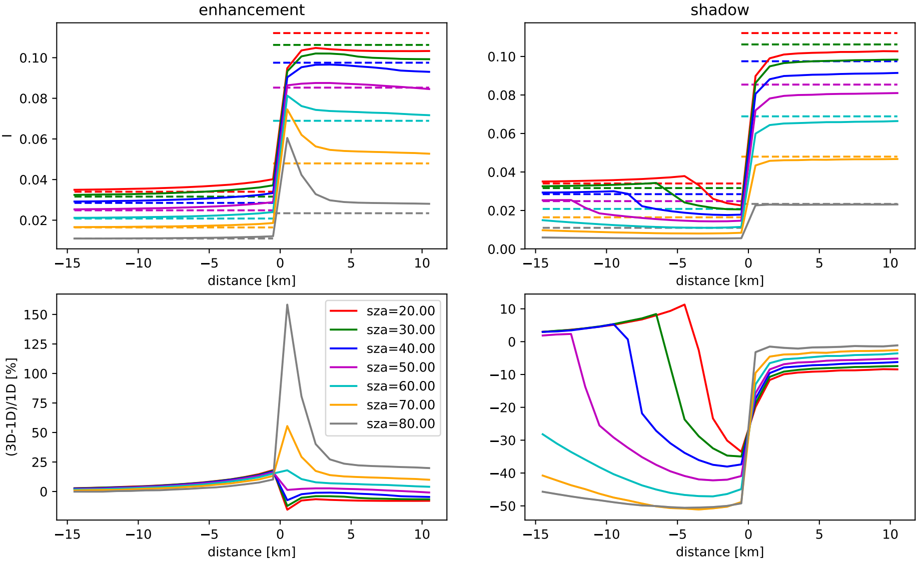
Other settings

- NO_2 profile: European polluted
- surface albedo: 0.05
- solar zenith angle: 50°
- no aerosol

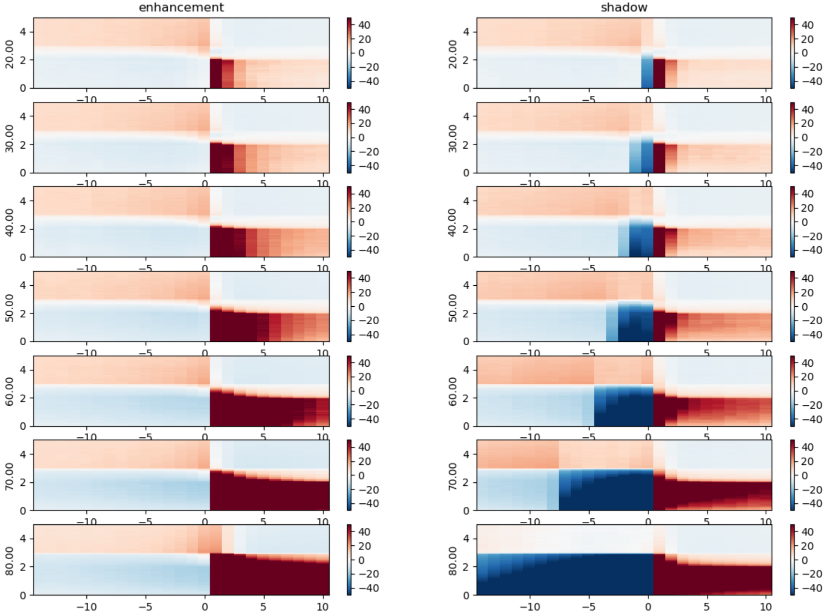
Radiance simulations for various solar zenith angles low cloud



Radiance simulations for various solar zenith angles high cloud



3D scattering impact (SZA) – low cloud



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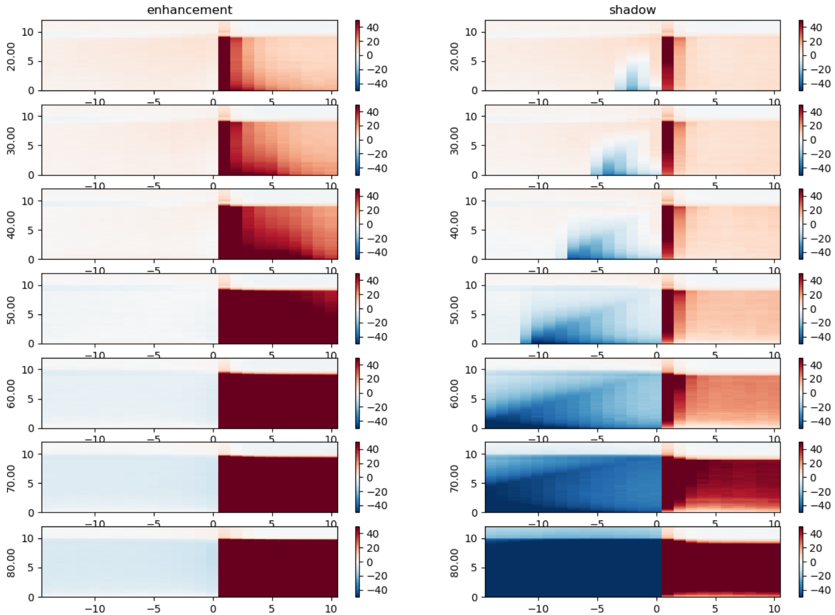


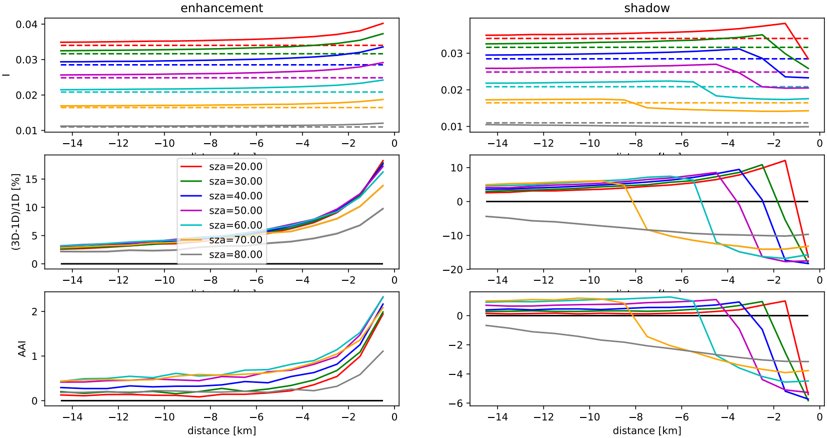
Can aerosol absorption index be used to detect cloud shadows?

- Aerosol absorption index widely used as an indicator for presence of absorbing aerosol
- Definition of TROPOMI AAI (as in Kooreman et al., AMT, 2020):

$$\mathrm{AAI} = -100 \cdot \left[\log_{10} \left(\frac{R_{340}}{R_{380}} \right)^{\mathrm{meas}} - \log_{10} \left(\frac{R_{340}}{R_{380}} \right)^{\mathrm{sim}} \right]$$

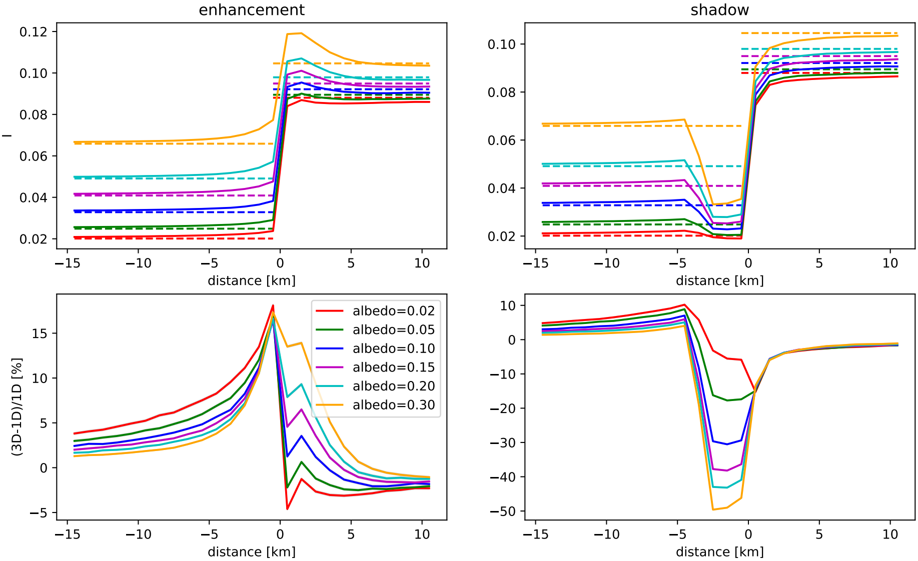
- Kooreman et al. investigated impact of clouds on AAI and cleary find cloud scattering features as the general angular dependance of Mie scattering (even the cloudbow is clearly visible)
- Are cloud shadows visible in AAI?

Cloud shadow and AAI – low cloud

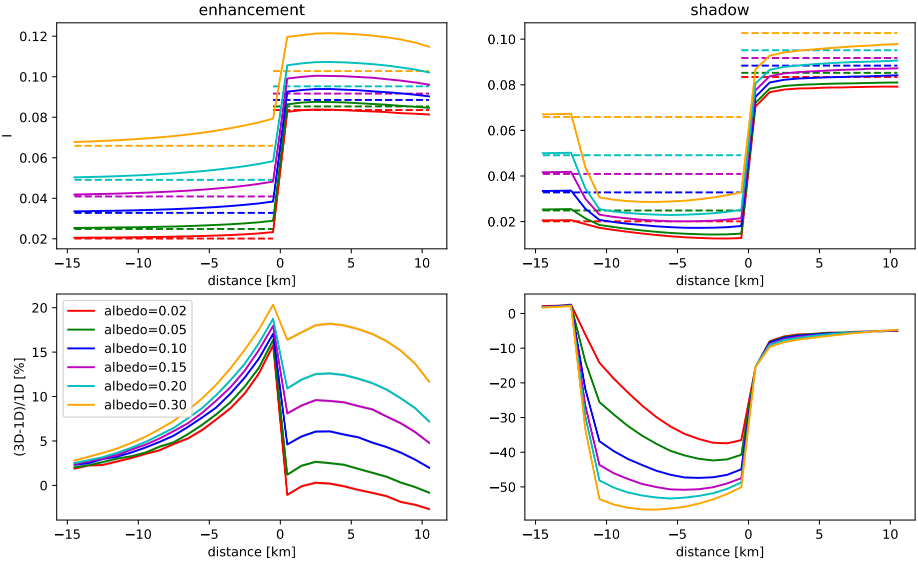


- Relative difference between 3D and 1D simulation very similar to AAI ⇒ negative AAI could indicate cloud shadows
- $\mathrm{AAI} = -100 \cdot \left[\log_{10}\left(\frac{R_{340}}{R_{380}}\right)^{\mathrm{3D}} - \log_{10}\left(\frac{R_{340}}{R_{380}}\right)^{\mathrm{1D}}\right]$
- Possible problem: calulation of AAI from observations requires simulation of clear sky radiances. This requires assumptions about atmospheric state ...

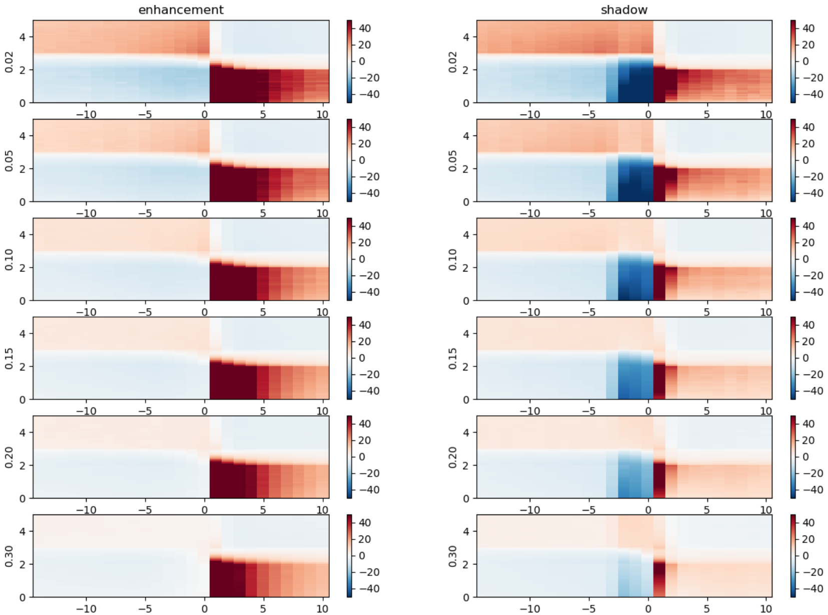
Radiance simulations for various surface albedos low cloud



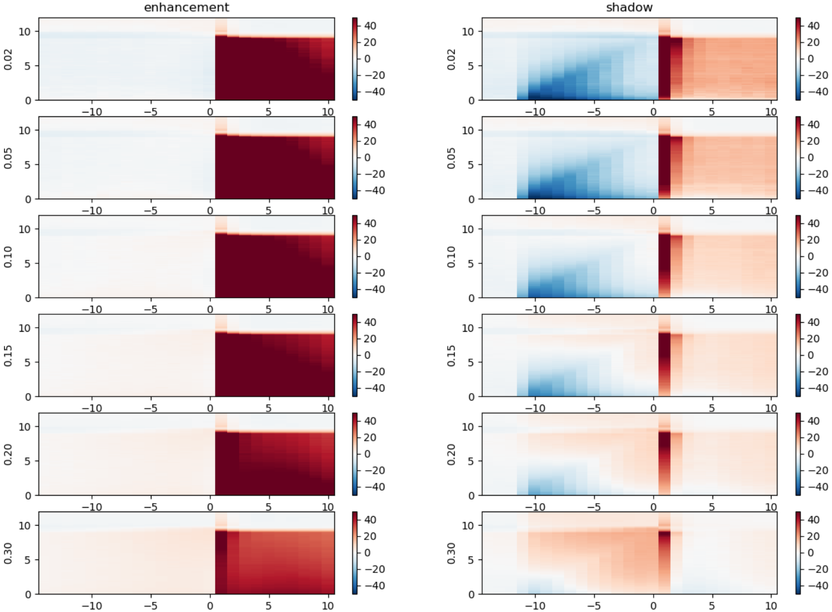
Radiance simulations for various surface albedos high cloud



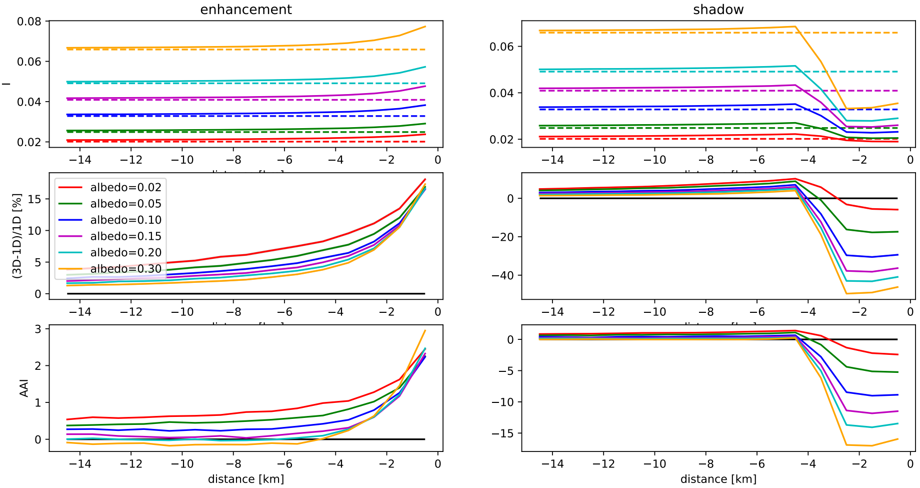
3D scattering impact (albedo) – low cloud



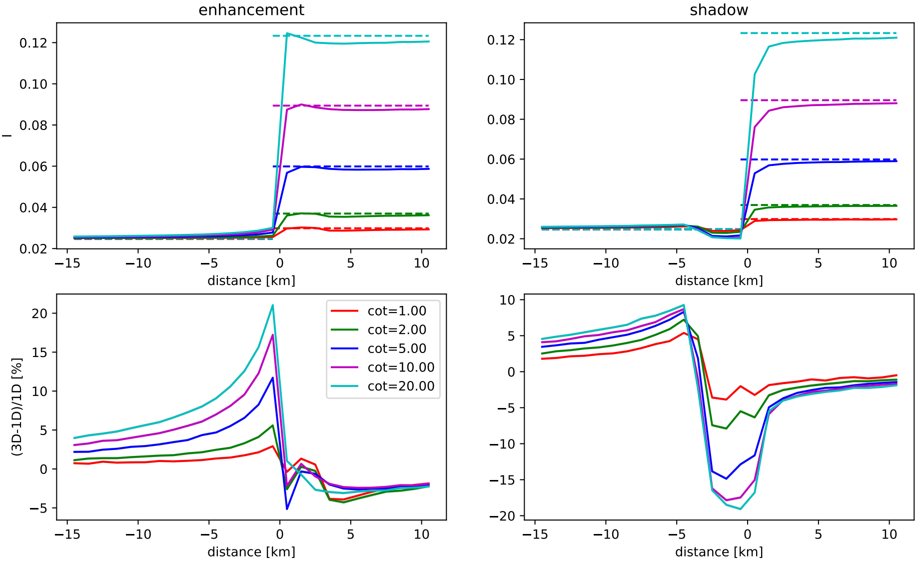
3D scattering impact (albedo) – high cloud



Cloud shadow and AAI – low cloud



Radiance simulations for various cloud optical thicknesses – low cloud



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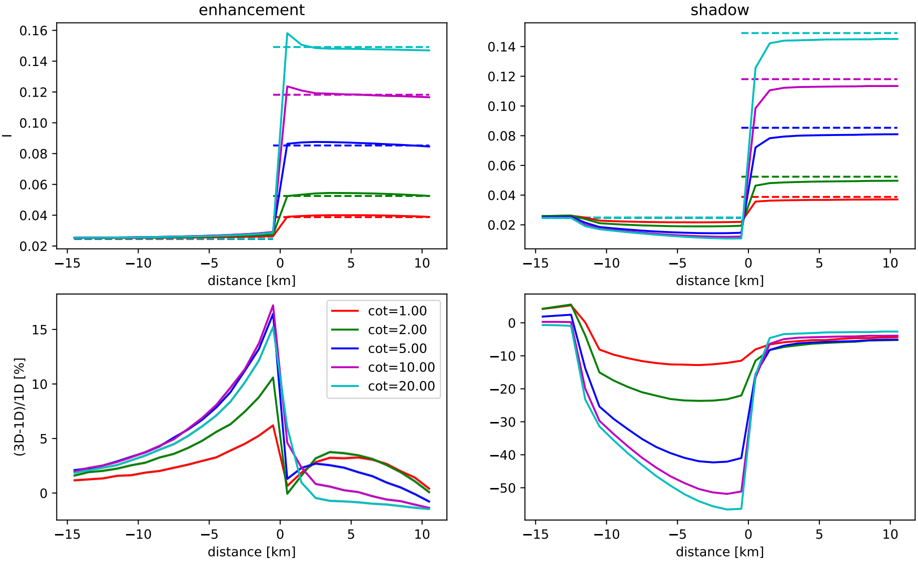
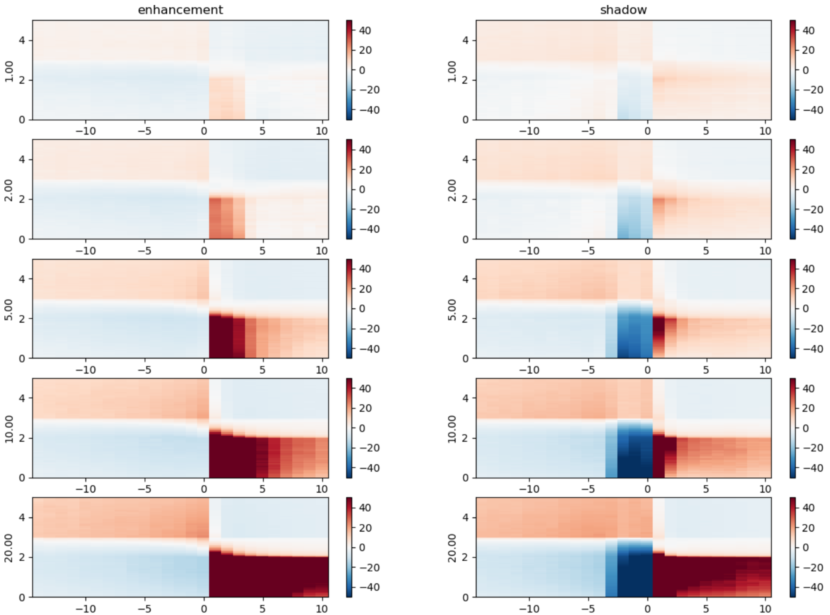


3D scattering impact (COT) – low cloud



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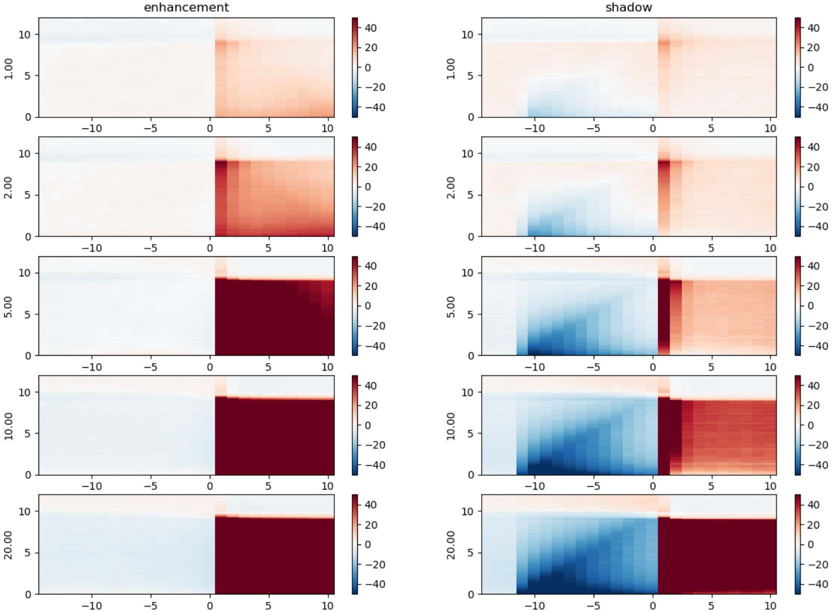
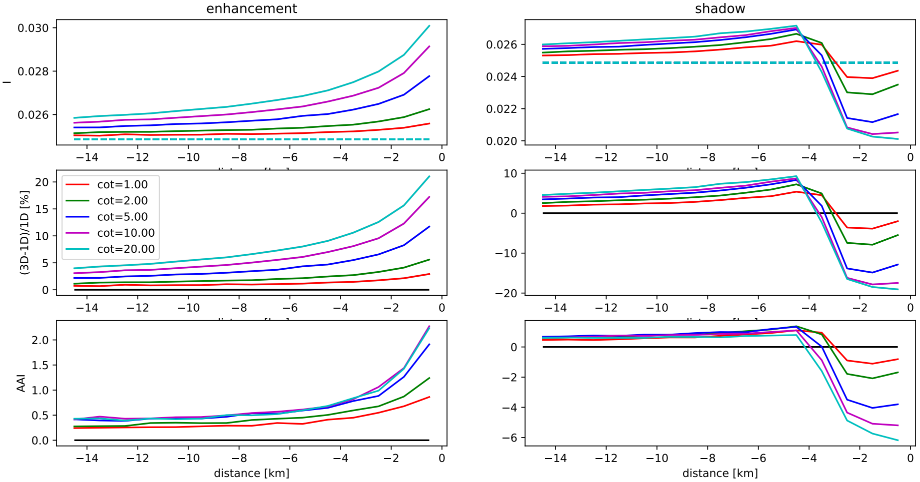


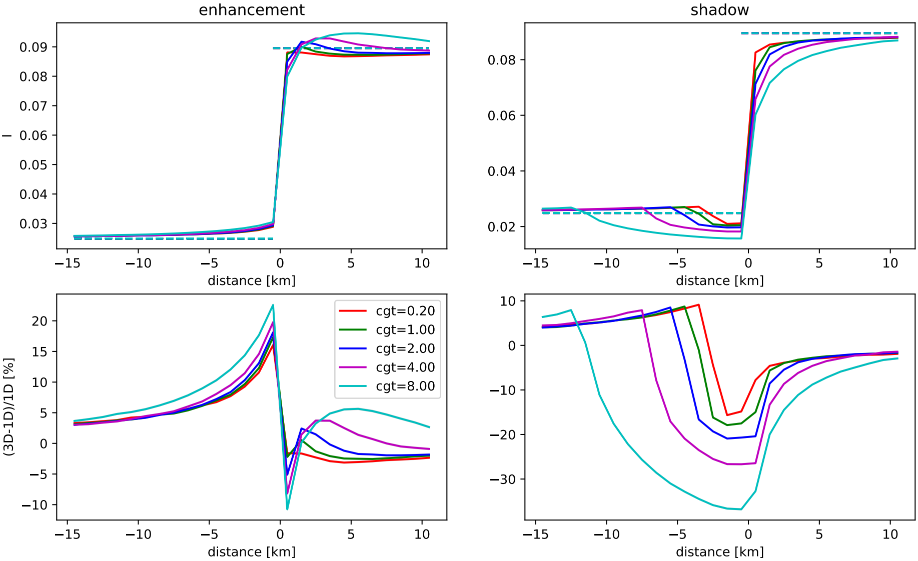
Cloud shadow and AAI – low cloud



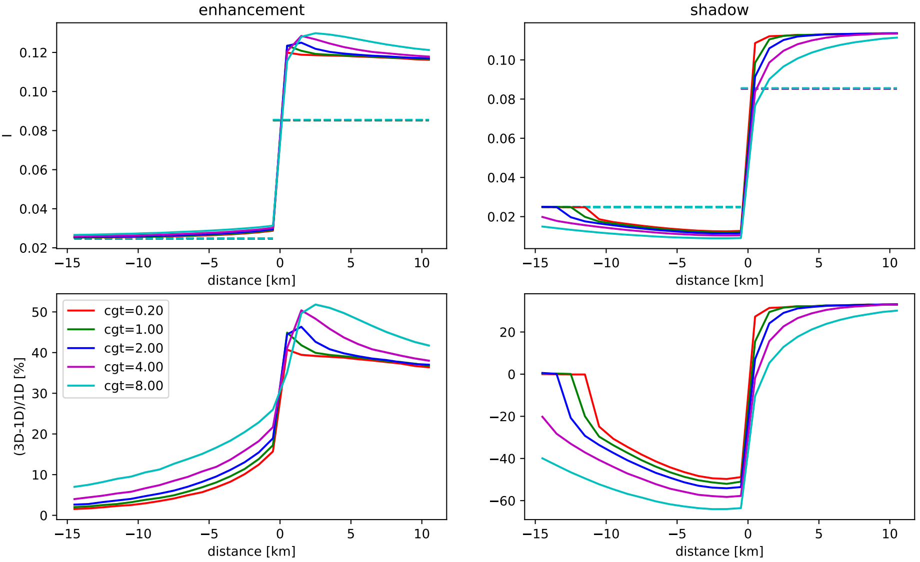
Summary of progress since PM6

- New 2D cloud simulations using high ice cloud as base case
  - Impact of solar zenith angle, albedo, cloud optical thickness, cloud geometrical thickness and cloud bottom height on NO_2 retrieval error
  - Comparison between 3D and 1D simulations allows to quantify 3D cloud scattering impact
- Simulations in UV spectral range to investigate, whether cloud shadows may be detected in aerosol absorption index (AAI)
  - Negative simulated AAI corresponds to cloud shadows
  - Questions: Calculation of AAI from observations requires assumptions for clearsky simulations, how well are these known? How stable is ratio $\frac{R_{340}}{R_{380}}$?
- Detailed investigation of NO_2 retrieval error due to cloud scattering ongoing $\Rightarrow$ WP300

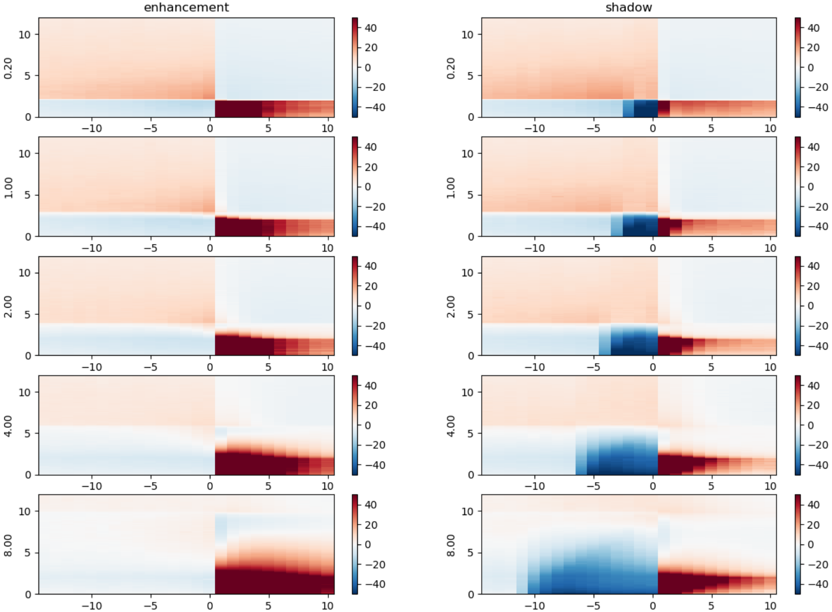
Radiance simulations for various cloud geometrical thicknesses – low cloud



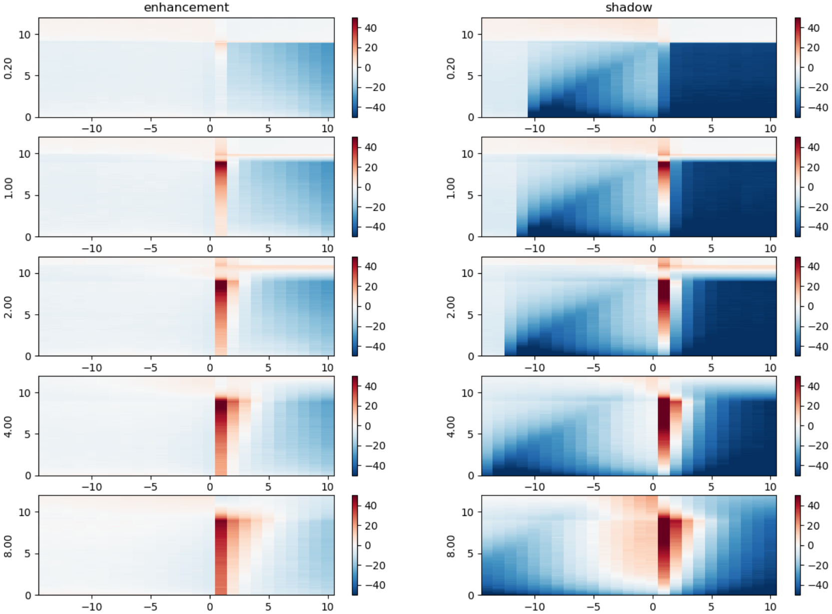
Radiance simulations for various cloud geometrical thicknesses – high cloud



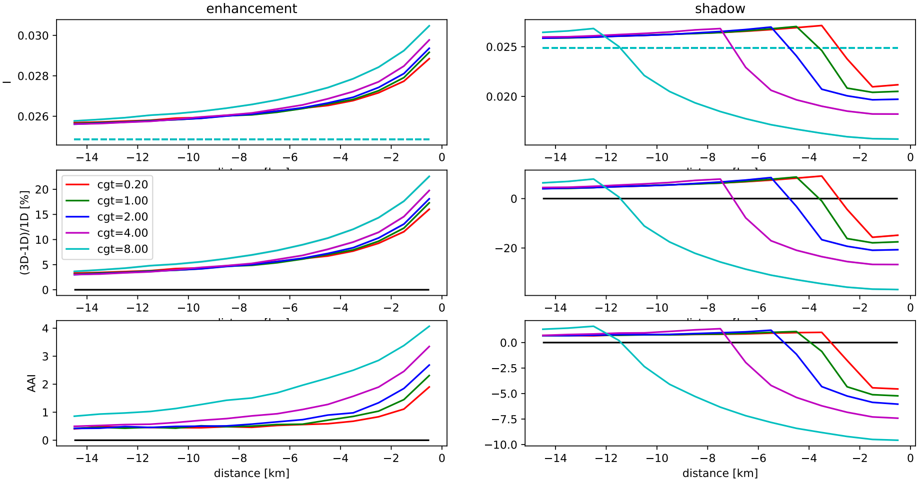
3D scattering impact (CGT) – low cloud



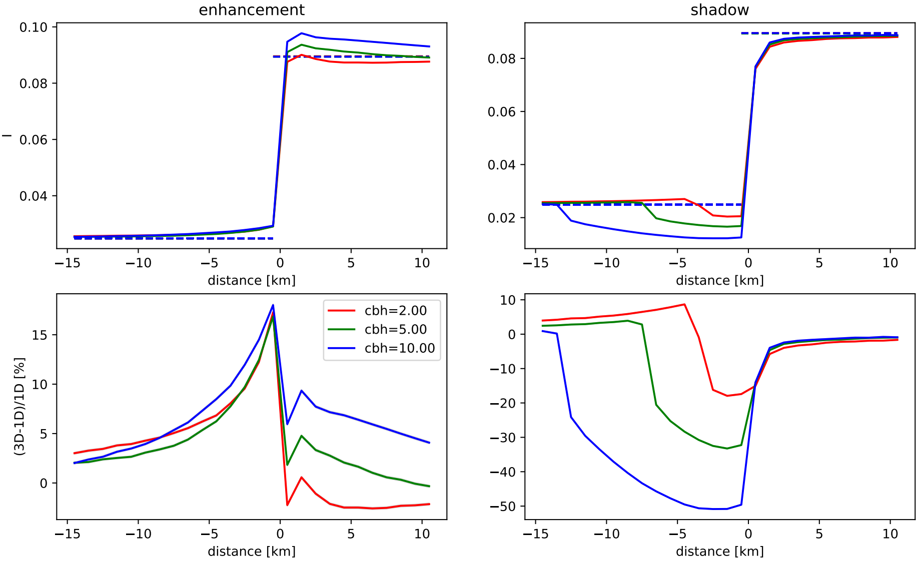
3D scattering impact (CGT) – high cloud



Cloud shadow and AAI – low cloud



Radiance simulations for various cloud bottom heights – low cloud



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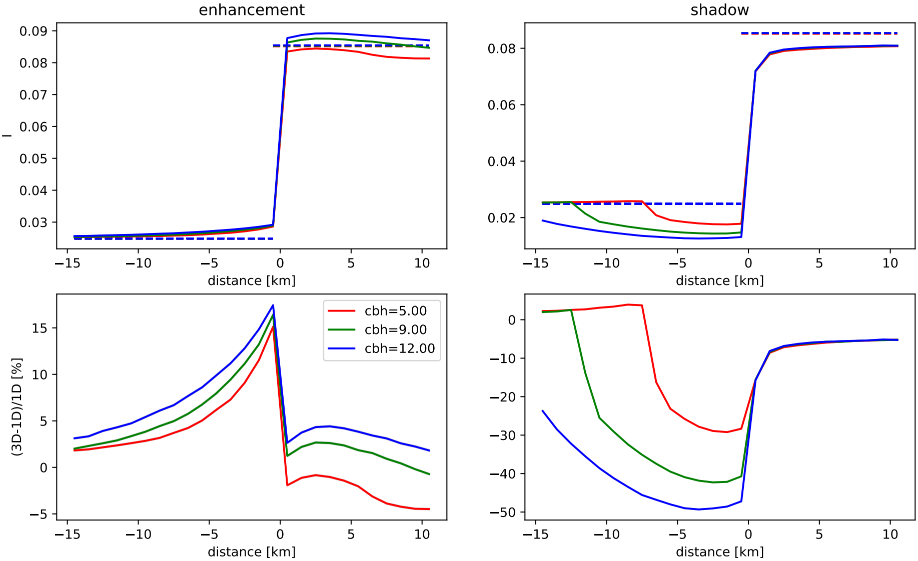
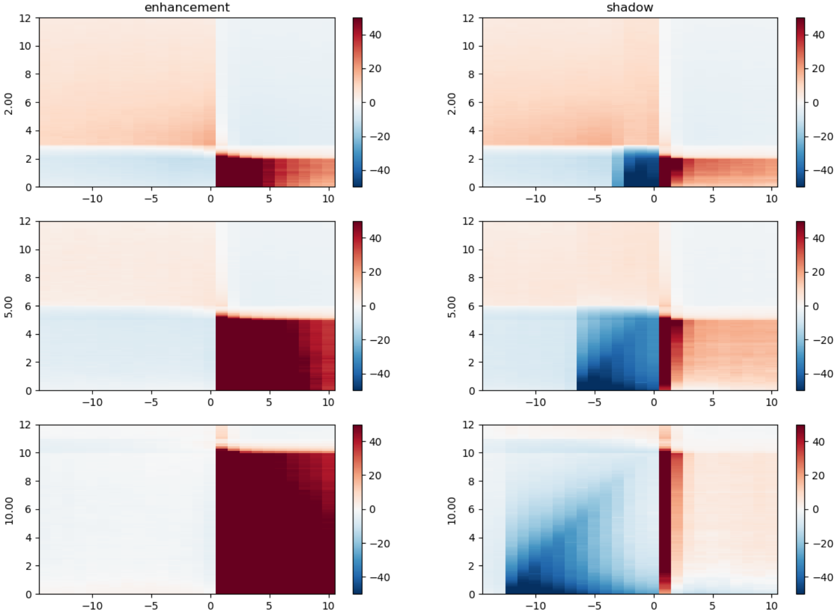
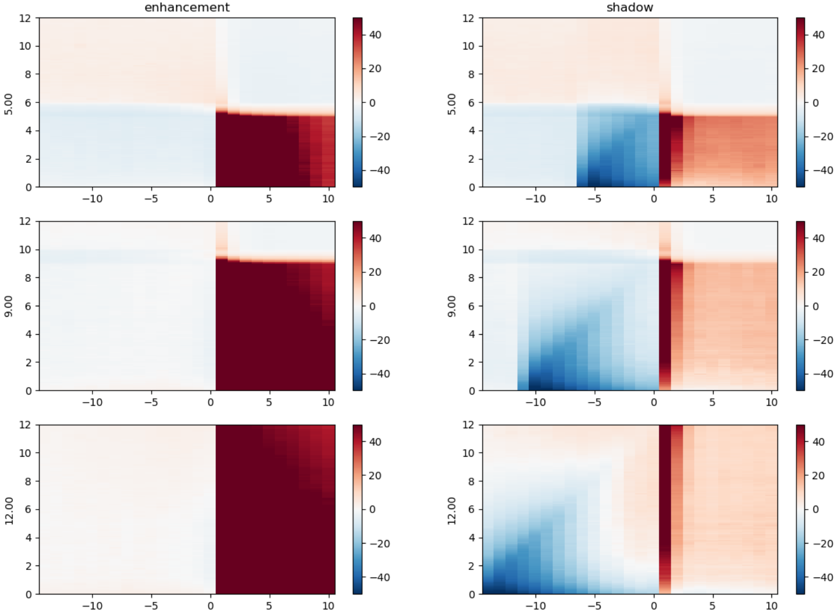


3D scattering impact (CBH) – low cloud



3D scattering impact (CBH) – high cloud



Cloud shadow and AAI – low cloud