Detectability of polar stratospheric clouds using the colour index retrieved from ground-based spectroscopic measurements

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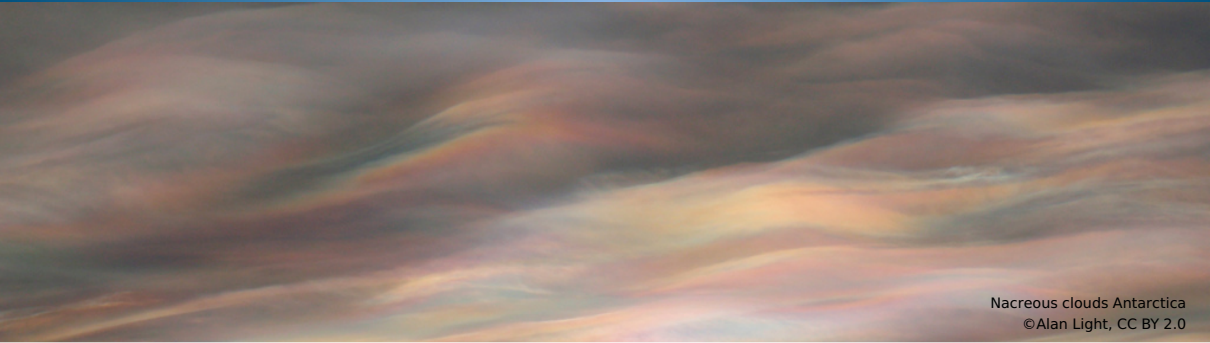

Nacreous clouds Antarctica

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Abstract

Motivation

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- Polar Stratospheric Clouds (PSCs) are an important component of ozone depletion
- Additional scattering by particles can be identified based on the Colour Index (CI) (Sarkissian et al., 1991; von Savigny et al., 2005)

$$\mathrm{CI} = \frac{I(\lambda_1)}{I(\lambda_2)}, \quad \lambda_1 > \lambda_2$$

- Thus, ground-based zenith DOAS observations enable the detection of PSCs for various weather conditions

  DOAS = Differential Optical Absorption Spectroscopy,
  originally designed to retrieve column densities of trace gases such as BrO or OClO

- Valuable complement to satellite retrievals

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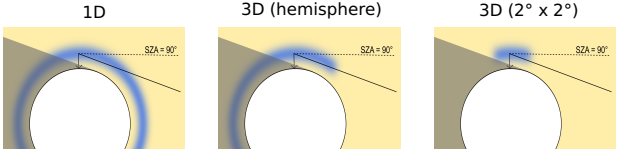
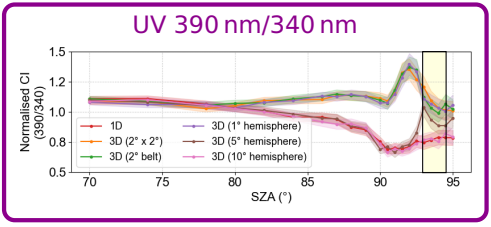
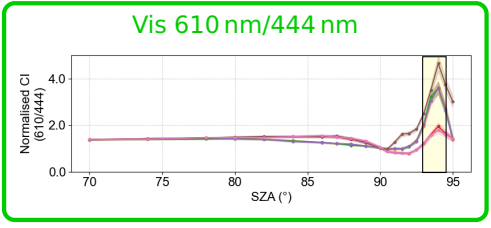
- Monte Carlo atmospheric radiative transfer model (Deutschmann et al., 2011)



- Dependency on location and extent of the PSC layer (also see Gomez-Martin et al. (2021))
- Realistic scenario: extension of 10° north of the Antarctic research station Neumayer (71 °S, 8 °W)
- Yielding similar results to 1D case





Simulation of PSC layer with $\tau_{PSC} = 0.05$ at 20 km to 22 km altitude

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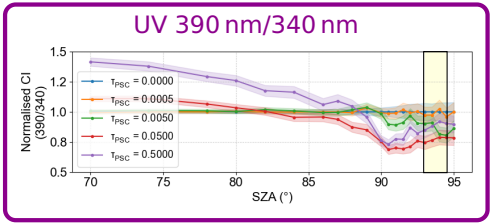
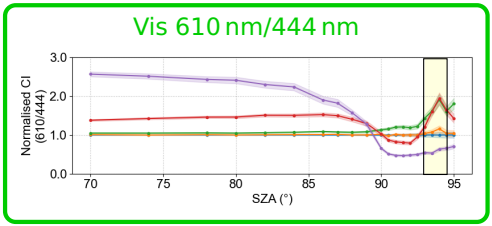
UV ► Reduced CI at high SZA

Vis ► CI peak at about 94° SZA
► But strong reduction in CI for optically very thick PSC layers

Next slides:

- Tropospheric cloud layer
- Influence of PSC layer altitude





Simulation of PSC layer at 20 km to 22 km altitude

Radiative Transfer Simulation
1D Simulations

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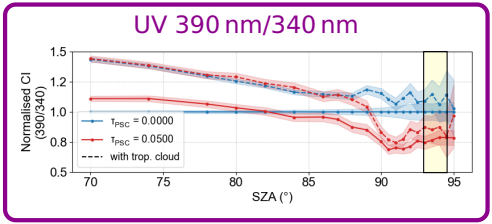
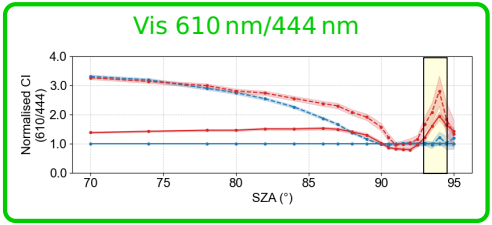
Tropospheric cloud layer

- Additional cloud layer with AOD = 5 at 3 km to 4 km altitude
- Enhanced CI for simulation with tropospheric cloud (dotted lines)
- Signature independent of PSC layer
- Especially strong effect at SZA < 90°





Simulation of PSC layer at 20 km to 22 km altitude

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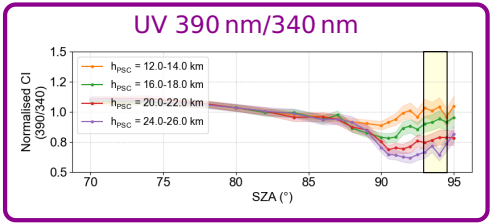
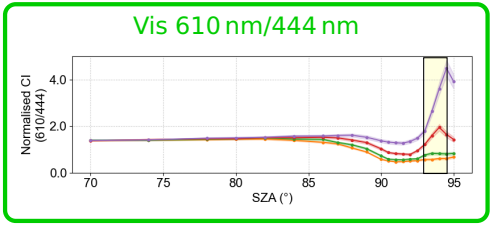
Influence of PSC layer altitude

- Typically PSCs form at high altitudes (up to > 25 km) and descend to near 15 km by the end of winter (Tritscher et al., 2021)
- Generally stronger signals are observed for high-altitude PSC layers





Simulation of PSC layer with $\tau_{PSC} = 0.05$

Neumayer DOAS
Comparison to Simulations Results

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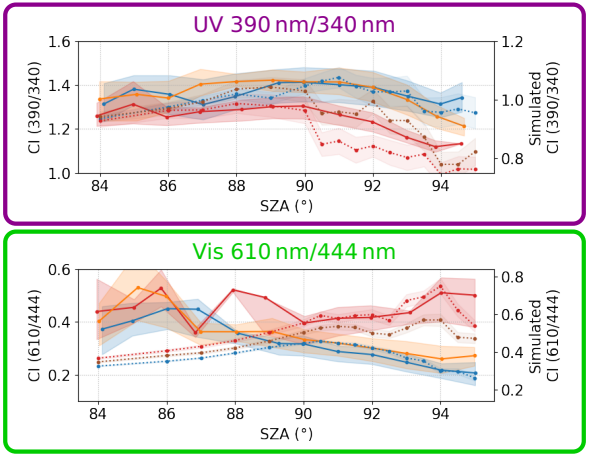
- Antarctic research station Neumayer (71 °S, 8 °W)
- Operating since 1999
- Good agreement to radiative transfer simulation



Baseline: Feb-April data
Simulation of PSC layer at 20 km to 22 km altitude

Neumayer DOAS

Time Series of the PSC Occurrence

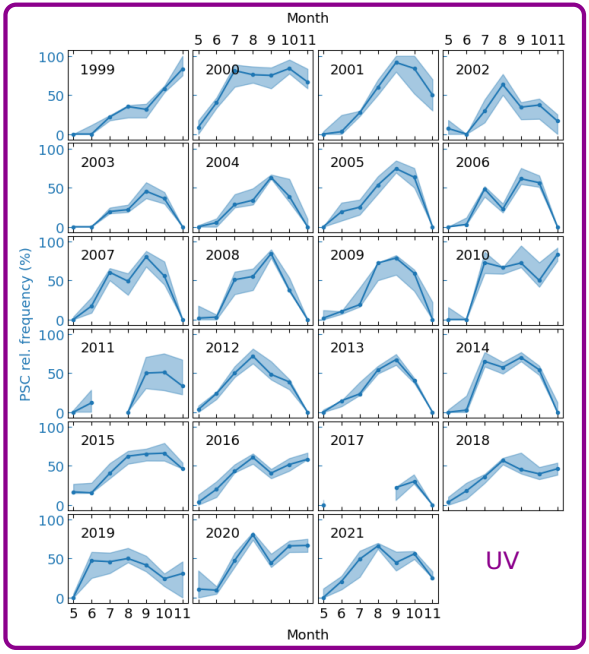
- Antarctic research station Neumayer (71 °S, 8 °W)
- Operating since 1999

- Good agreement to radiative transfer simulation

UV ► About 37% PSC occurrence

Vis ► Less PSCs (21%) detected

- PSC season lasts until mid-November
- No significant trend visible
- **Note:** Tropospheric clouds add to uncertainty (+20% in the **UV**)



Neumayer DOAS
Time Series of the PSC Occurrence

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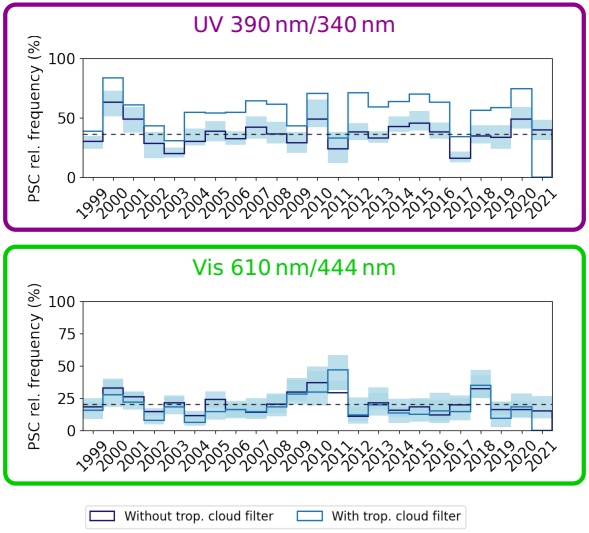
- Antarctic research station Neumayer (71 °S, 8 °W)
- Operating since 1999
- Yearly average PSC frequency for the analysis with and without tropospheric cloud filter
- No significant trend visible
- Tropospheric cloud filter is based on O_4 measurements and ECMWF cloud fraction data
- Tropospheric clouds add to uncertainty (+20% in the **UV**)



Kiruna DOAS
Comparison to Simulations Results

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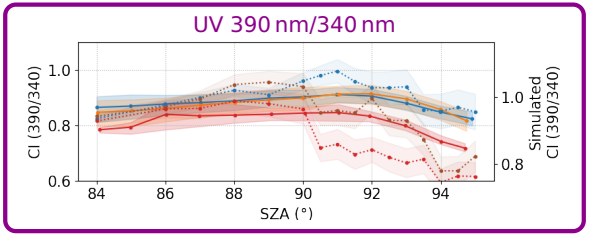
- Kiruna, Sweden (68 °N, 20 °E)
- Operating since 1997
- Similar findings to Neumayer DOAS



Data:
- Baseline
- No PSC
- PSC

Simulation:
- τ_{PSC} = 0.0000
- τ_{PSC} = 0.0050
- τ_{PSC} = 0.0100

Baseline: June-Oct data
Simulation of PSC layer at 20 km to 22 km altitude

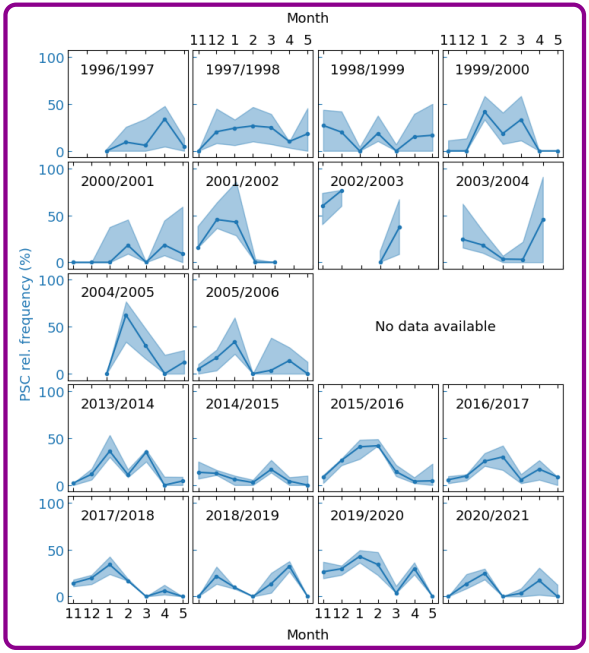
Only UV spectrometer available

Kiruna DOAS
Time Series of the PSC Occurrence

- Kiruna, Sweden (68 °N, 20 °E)
- Operating since 1997
- Similar findings to Neumayer DOAS

UV
- About 18% PSC occurrence

- High uncertainty for first detector prior 2013
- Occasionally unexpected PSC-like signal in spring (might be caused by volcanic aerosol)



Conclusions

- **Colour Index (CI) method yields the possibility to retrieve a local PSC signal on a statistical basis for data sets in both hemispheres**
  - CI is dependent on optical density, altitude and extent of the PSC layer, as well as the chosen wavelength ratio
  - Optically thick tropospheric cloud layers may influence the retrieval
  - PSCs are more than twice as frequent above Neumayer as above Kiruna

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