Potential influence of volcanic aerosol on the colour index of ground-based spectroscopic measurements

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Motivation

- Polar Stratospheric Clouds (PSCs) are an important component of ozone chemistry
- Ground-based spectroscopic measurements can be taken to detect PSCs using the so-called colour index (CI)
- Continuous long-term measurements from two DOAS (Differential Optical Absorption Spectroscopy) instruments at Kiruna, Sweden (68° N, 20° E), and at the German research station Neumayer, Antarctica (70° S, 8° W) are analysed

Colour Index

Additional scattering by particles, e.g. within PSCs, can be distinguished by characteristic wavelength dependencies (Sarkissian et al., 1991; von Savigny et al., 2005). This leads to changes in the CI compared to non-PSC conditions, which is defined as the ratio between observed fluxes at two wavelengths

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

Method

- Radiative transfer simulations show that **changes of CI mainly depend on** chosen wavelength ratio and **characteristics of the PSC layer**
- **PSC threshold** is obtained by finding **minimum CI** in the UV (or maximum CI in the visible) **during summer months** where no PSCs are to be expected
- Tropospheric clouds influence retrieval and can lead to an under- rather than overestimation of PSC occurrence

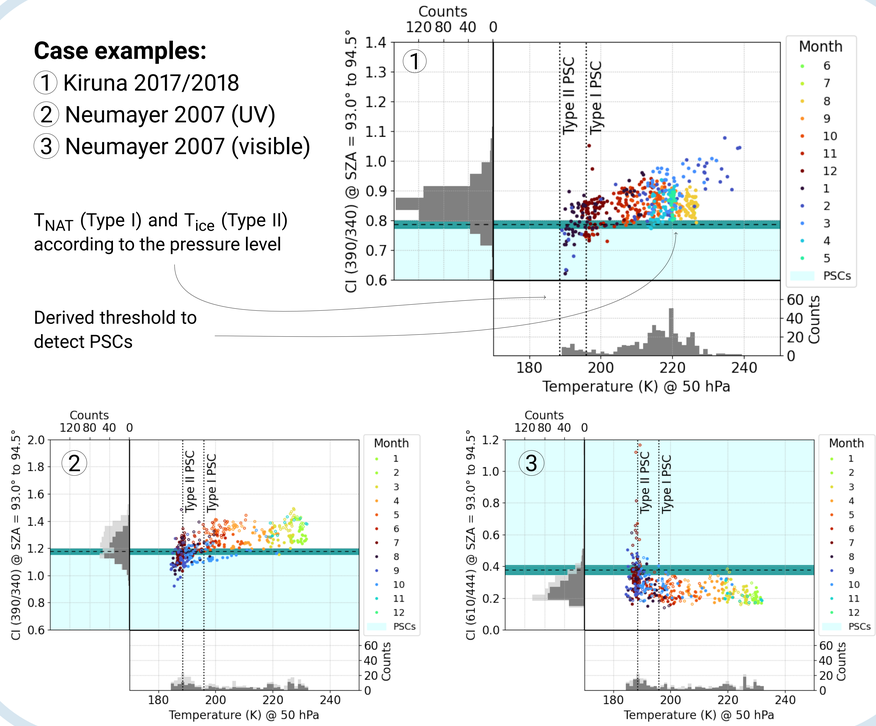
Seasonal Cycle

- Correlation between CI and temperature shows a **distinctive seasonal cycle**
- Similar behaviour is seen for different years and both measurement stations
- **Existence of PSCs in early spring is doubtful** considering the sedimentation and evaporation of PSC particles (e.g. Tritscher et al., 2021) ⇒ **other "residual" particles lead to enhanced scattering at high altitudes**

Case examples:
① Kiruna 2017/2018
② Neumayer 2007 (UV)
③ Neumayer 2007 (visible)

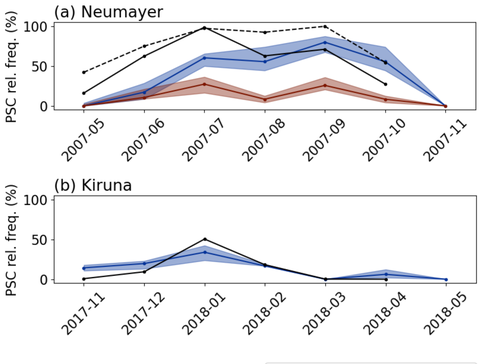
T_{NAT} (Type I) and T_{ice} (Type II) according to the pressure level

Derived threshold to detect PSCs



Comparison to Satellite Data

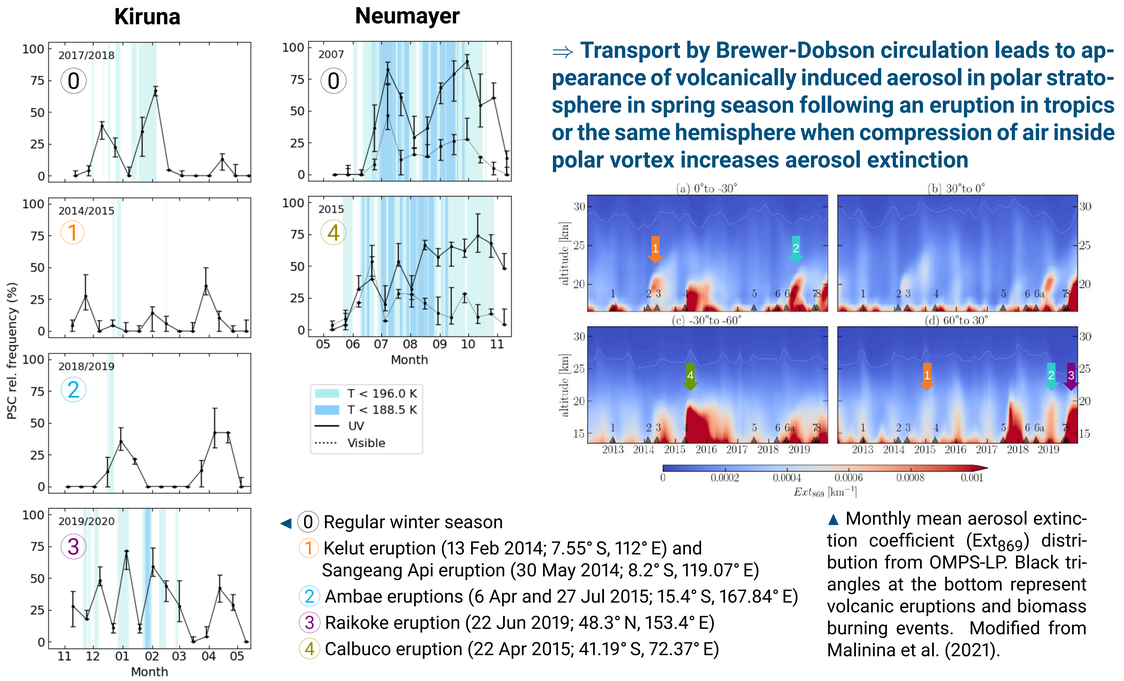
- **Reasonable agreement** to satellite-based PSC climatologies
- Note that PSC sightings can vary significantly within chosen sampling area (approx. 300 km × 300 km)
- DOAS UV data shows higher PSC occurrence towards spring
- Generally lower sensitivity to PSCs is indicated in the visible



Influence of Volcanic Aerosol

- Winter season shows **enhanced PSC occurrence during periods with temperatures below formation thresholds** of PSC particles
- Note that air masses can transport PSCs into the area without maintaining cold temperatures (esp. above Kiruna)
- On average over past 20 years, PSC relative frequency amounts to **18 % above Kiruna** and **37 % above Neumayer** (in UV) during the winter half year

- Unexpectedly high PSC-like signature observed for some spring seasons
  - Reduced total ozone columns in ECMWF and MERRA2 data
  - No indication of generally enhanced stratospheric background aerosol during spring
  - No indication of instrument malfunction
  - **Coincidence with volcanic eruptions in previous year**



⇒ **Transport by Brewer-Dobson circulation leads to appearance of volcanically induced aerosol in polar stratosphere in spring season following an eruption in tropics or the same hemisphere when compression of air inside polar vortex increases aerosol extinction**

◀ (0) Regular winter season
(1) Kelut eruption (13 Feb 2014; 7.55° S, 112° E) and Sangeang Api eruption (30 May 2014; 8.2° S, 119.07° E)
(2) Ambae eruptions (6 Apr and 27 Jul 2015; 15.4° S, 167.84° E)
(3) Raikoke eruption (22 Jun 2019; 48.3° N, 153.4° E)
(4) Calbuco eruption (22 Apr 2015; 41.19° S, 72.37° E)

▲ Monthly mean aerosol extinction coefficient (Ext_{869}) distribution from OMPS-LP. Black triangles at the bottom represent volcanic eruptions and biomass burning events. Modified from Malinina et al. (2021).

Conclusion

- Average PSC occurrence about 18 % above Kiruna and 37 % above Neumayer
- PSC occurrence measured at both stations exhibits no trend (not shown)
- Comparison to satellite retrievals shows largest deviations in the beginning and end of respective winter season
- Unexpectedly high PSC-like signature during spring likely due to induced volcanic aerosol particles in the stratosphere after large volcanic eruptions
- These additional particles might have implications on polar ozone chemistry

Paper as pdf

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Abstract as pdf

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