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Radiative transfer simulations of PSC signatures measured by CRISTA-NF during the RECONCILE campaign in winter 2009/2010

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In-situ particle measurements of polar stratospheric clouds (PSC) aboard the high altitude research aircraft M55-Geophysica during the RECONCILE campaign showed particle concentrations about one order of magnitude larger than proposed by Fahey et al. (Science, 2001) for nitric acid trihydrate (NAT) rocks. Here we use infrared (IR) limb spectra measured by the airborne instrument Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere (CRISTA-NF) to derive more information on the PSC particles' microphysical properties. We compare the measured IR spectra with radiative transfer simulations accounting for scattering based on the in-situ measured particle size distributions.

For the simulation of the IR spectra the atmospheric state was constrained by measured atmospheric profiles of trace gases, so that the remaining signatures are mainly due to cloud particles. Up to flight altitude temperature, pressure, and several trace gas profiles of the in-situ measurements, made aboard the aircraft, were incorporated. Above flight altitude ERA-interim and satellite data were employed.

The comparison of the measured IR spectra with simulated clear air spectra confirmed that cloud particles were present. A comparison with simulated clouds of different composition clearly showed that the PSCs at flight altitude did not contain ice. The simulations also showed that a PSC layer of about 5 km thickness with a size distribution as proposed by Fahey is not sufficient to reproduce the measured spectra.

Successful simulations of the IR spectra required to take into account the very complex cloud situation. Measurements indicated that tropospheric clouds were present and that the PSC was not homogeneous. Simulations with complex cloud information and measured particle size distribution generally showed a good agreement with the measurements when assuming either an optically thick tropospheric cloud or an optically thin tropospheric cloud combined with a PSC containing large particles only in the lowest layer.

A prominent feature at 820 cm^{-1} can be used to identify NAT in IR spectra. In our simulations this feature was generated only by small NAT particles. The measured CRISTA-NF spectra exhibit a distinct feature, very similar but slightly shifted, at around 816 cm^{-1}. We found that trace gases that have band centers around 820 cm^{-1} are not the origin of this feature. Information from literature and calculations of extinction coefficients and single scattering albedos indicate that this NAT feature may be shifted towards smaller wave numbers when non-spherical particles instead of spherical particles are present. If the non-sphericity of these particles can be confirmed, this might have implications for the discrepancy between the measured and the proposed NAT rock particle size distributions.