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Atmospheric Measurement Techniques Discussions

Interactive comment on "Radiative transfer simulations and observations of infrared spectra in the presence of polar stratospheric clouds: Detection and discrimination of cloud types" *by* Christoph Kalicinsky et al.

Anonymous Referee #2

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The paper describes methods to detect PSCs and to classify them. The following PSC types are distinguished: NAT (nitric acid trihydtrate), STS (supercooled ternary solution) and ice clouds. For the detection of small NAT particles, a spectral feature at about 820cm-1 has often been used. The authors show, that for larger NAT particles this feature shifts towards smaller wavenumbers and they use this feature to further specify the NAT particles as sNAT (small particles), mNAT (medium particles), and lNAT (large particles). Ice is detected by using the difference between 2 spectral regions (~833cm-1 and ~950cm-1), the radiance is similar in clear sky conditions but

significantly smaller at 950cm-1 when ice is present, a well-known feature which has already been used before. When the cloud is neither NAT nor ice, it is classified as STS. Further a method based on the so-called Cloud Index (CI) is developed to derive the cloud bottom height.

The methods are applied to a comprehensive set of radiative transfer simulations including NAT, ice and STS, all with various concentrations and particle size distributions. Based on the simulations it is demonstrated that the methods work well, in particular sNAT can be distinguished very well from the larger NAT particles mNAT and lNAT. Finally the new methods are also applied to observations of the CRISTA-NF instrument taken during a flight of the RECONCILE campaign.

Generally the newly developed methods are described quite well and the figures are appropriate. However, I think that some clarifications are needed, in particular the motivation is not so clear for readers who do not work in the specific field of research (see also my comments below). The scope of the paper fits AMT very well, therefore I recommend publication after taking into account the comments below.

General comments:

* The motivation is not clear. It is said in the abstract that there are "uncertainties in the representation of PSCs in model simulations". Which models? Atmospheric chemistry models, climate models? Please provide some examples of models which can be improved by better knowledge of PSC properties. Which properties are required by these models? What are the most relevant parameters? Composition, concentration, size, shape ...? The methods presented here do not derive number concentrations, can these also be derived from spectral IR observations? How important is the classification into different size regimes?

* Cloud optical thickness is a useful parameter to describe a cloud, the term is sometimes used in the paper but no number is given. What is the optical thickness range of the clouds considered here (in the RT simulations and what can be observed using the

limb observations)? I suppose that all clouds are optically very thin, what is the upper limit of cloud optical thickness that can be analysed with the presented methods?

* The radiative transfer simulations are based on a single scattering approach which is not described in detail here. This also means that it is only valid for very thin clouds, for which multiple scattering can be neglected (see e.g. Höpfner and Emde 2005). Please provide the optical thickness range used for the radiative transfer simulations to justify the neglect of multiple scattering.

* Presuambely, the JURASSIC model does not account for horizontal inhomogeneities. Please discuss the validity of this approach for PSCs, i.e. how large is the horizontal extend of the PSCs typically compared to the line of sight through the PSCs?

* For the reader it is rather difficult to remember the definition of all indices used in the paper. I think it would be helpful to include a figure showing the spectral regions used and mark the spectral windows that are used to calculate the individual indices. Also a table including the definitions of NAT-indices 1,2,3 and the CI index could be useful.

* I miss some discussion about the uncertainties. For example on p.8 you write: "Nearly all simulations with NAT particles < 3 μm lie above the region of the simulations for STS and ice clouds, which is marked by the solid black line. Thus, NAT particles within this size range can be detected and discriminated using NAT index-1." For the modelled spectra this is correct, but also for real observations? Measurements always include uncertainty, how accurate measurements are required so that NAT is clearly separated from the ice clouds?

Specific comments:

* The title is a bit misleading. The main focus of the paper are the methods to classify and detect PSCs. I thought from reading the title starting with "Radiative transfer" that the paper was more about radiative transfer methods etc. For the RT simulations a well-known model JURASSIC is applied but the methodology is not described in this

paper. Also the observational methods are not described here. I think that the title should be something like e.g. "A new method to detect and classify polar stratospheric clouds"

* Abstract: p1, l7 "... showed a spectral peak at about 816 cm-1 . This peak is shifted compared to the peak at about 820 cm-1, which is known to be caused by small NAT particles. " -> A bit more information about this peak would be helpful. What is the physical process responsible for the peak. Which physical processes could produce a shift of a spectral peak ...

p1, l16: "gradient of the CI" -> which gradient is meant here? -> "vertical gradient"

p3, l31-33: These 3 sentences should be shifted to Section 2.2

p4. l19: Title of section should include the term "radiative transfer simulations"

p4 l32: "The optical properties of the particles, extinction coefficient, scattering coefficient, and phase function, required for the radiative transfer simulations ..." -> "The optical properties of the particles (extinction coefficient, scattering coefficient, and phase function) required for the radiative transfer simulations ...", include brackets here because extinction coefficient, scattering coefficient, and phase function are the optical properties

p7 l20: What is the "scattering radius" of a particle, this term has not been defined

p7 l31: "different contributions of extinction and scattering" -> extinction is the sum of absorption and scattering, therefore I think that you mean "absorption and scattering"

Fig.1 and 5: "spectra have been scaled such that the radiance equals 1" -> scaling factor is not clear, is it the average radiance over the plotted spectral range?

Fig.2: For the interpretation of the RT simulations, it would help to include here also the refractive indices of ice and STS. Further I think that it would be very helpful to show extinction and absorption coefficients, which are probably calculated using Mie theory

for the individual PSC types and for some particle sizes to see, that for larger particles the scattering coefficient dominates.

p9, l4: "results for PSCs with larger NAT particles (up to 4 μm) also lie above the simulations for STS and ice (black separation line)": In Fig.3 it is not well visible, which radii lie above the separation line. May be discrete colours could be used for each of the simulated radii?

p9, l23: "detected NAT spectra" -> NAT is detected, not the "spectra"

p10, l23: "When the NAT detection and classification procedure (described in the previous subsection) is applied to the simulation results for the mixed clouds, the good discrimination between the small and medium size particles remains." -> this is not shown, why?

p13, l3-9: Here you discuss about "cloud optical thickness" (thick and thin) without providing any values -> as mentioned above, please quantify the cloud optical thickness.

p15, l7: "... where much more NAT was observed by CALIOP (the difference in the Southern hemisphere is much smaller)"-> how much more NAT was observed by CALIOP, how much smaller is the difference in the Southern hemisphere?

p16 l20: "This method can surely be transferred to other cloud observations such as cirrus clouds and aerosol layers and to other airborne instruments measuring in the same wavelength region like e.g. GLORIA." -> Which clouds and aerosols could be observed? Probably only very thin clouds? Up to which cloud optical thickness can the method be applied?

Reference:

* M. Hoepfner and C. Emde. Comparison of single and multiple scattering approaches for the simulation of limb-emission observations in the mid-IR. J. Quant. Spectrosc. Radiat. Transfer, 91(3):275-285, March 2005.

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