I would like to thank the reviewers for their comments which have helped us to improve the manuscript and make it a more useful work for other researchers. I have addressed their comments as follows (indicated in blue as in the revised manuscript).

Reviewer 2

The manuscript presents a simplified formulation to reproduce and understand the behavior of the color index (CI) at high solar zenith angles (SZA) in the presence of optically thin high-altitude clouds, such as polar stratospheric clouds, without the need to solve the full radiative transfer problem. Based on the improved mechanistic understanding, a new so-called Rayleigh-referenced CI is introduced, defined as the ratio between the measured zenith intensity at a single wavelength and the corresponding intensity expected from a purely Rayleigh-scattering atmosphere. The method is verified and tested across a range of relevant parameters using comprehensive spherical radiative transfer simulations.

The work aligns well with the scope of AMT, and I recommend publication after addressing the following minor points.

General comments

-The manuscript is submitted by a single author, yet the text consistently uses the first-person plural ("we"). To enhance clarity and conform to standard academic conventions, I recommend adopting a more neutral tone throughout. For example, in line 7:
"In this work, we introduce …." -> "In this work, …. is introduced."
*Author response: The manuscript has been revised throughout to replace the first-person plural with neutral or passive constructions.
-The definition of z_dark (ll. 117–119 and 180–187) is not entirely clear. As I understand it, z_dark refers to the lowest altitude illuminated by the Sun. However, the text describes it as an upper threshold. Please clarify the exact meaning of z_dark and its usage in the formalism. If possible, include z_dark in Fig. 1 to improve illustration and interpretation.
*Author response: We thank the reviewer for this comment. The original definition of z_{dark} was indeed ambiguous and has been replaced by the following clearer description:

'*Here, z_{top} denotes the altitude of the top of the atmosphere, while z_{dark}, which depends on the SZA, denotes the lowest altitude that still receives direct solar illumination during twilight. Below z_{dark}, direct solar radiation is completely blocked by the Earth's curvature.*'

-Given that high-altitude clouds have primarily been studied in remote regions using the color index method, how strongly does the absorption by NO2 (and also O3, H2O) affect the cloud height retrieval if the chosen wavelength pair is suboptimal? Please comment on the expected magnitude of such effects (Sect. 3.4 / Fig. 7).
*Author response: The impact of gaseous absorption on the retrieved SZAmax depends on whether the absorption modifies the CI signal close to, or far from, the SZA at which the maximum occurs. This, in turn, depends on several factors, including the cloud altitude, the selected wavelengths, the gaseous absorption optical depth, and the vertical distribution of the absorbing species.
To illustrate this behaviour, several tests were performed using different combinations of λ1 and λ2, assuming the presence of a gas that absorbs at λ1 but not at λ2. The total gaseous absorption optical depth was varied between 0.01 and 0.1, and a Gaussian vertical distribution

centred at 20 km with a geometrical thickness of 10 km was assumed. Although the resulting modifications of the CI signal can be substantial, depending on the gaseous absorption optical depth, the position of the SZA maximum may remain almost unchanged. This is because SZAmax is determined by the intersection between the relative SZA variations of the signals at the two wavelengths. Therefore, if the gaseous absorption does not significantly modify these relative variations in the vicinity of this intersection, only a small displacement of SZAmax is expected.

Figure 1 shows representative simulations of the CI with and without gaseous absorption for a cloud layer located at 18 km and a total gaseous absorption optical depth of 0.05. In all cases, λ1 is fixed at 400 nm, while λ2 = 800, 700, 600 and 500 nm (different panels of the figure). These examples show that introducing the absorbing layer can substantially modify the shape and amplitude of the CI signal. However, the corresponding variation of SZAmax depends strongly on the selected wavelengths. In particular, the smaller the spectral separation between λ1 and λ2, the larger the displacement of SZAmax. For the 400/800 nm combination, the displacement is only about 0.01°, whereas it increases to approximately 0.05°, 0.21°, and 0.43° for the 400/700 nm, 400/600 nm, and 400/500 nm combinations, respectively.

It is also important to note that increasing gaseous absorption reduces the absolute radiance reaching the instrument at the absorbing wavelength. Therefore, even when the displacement of SZAmax is small, the sensitivity of the cloud detection may still decrease because of the lower signal available for the retrieval.

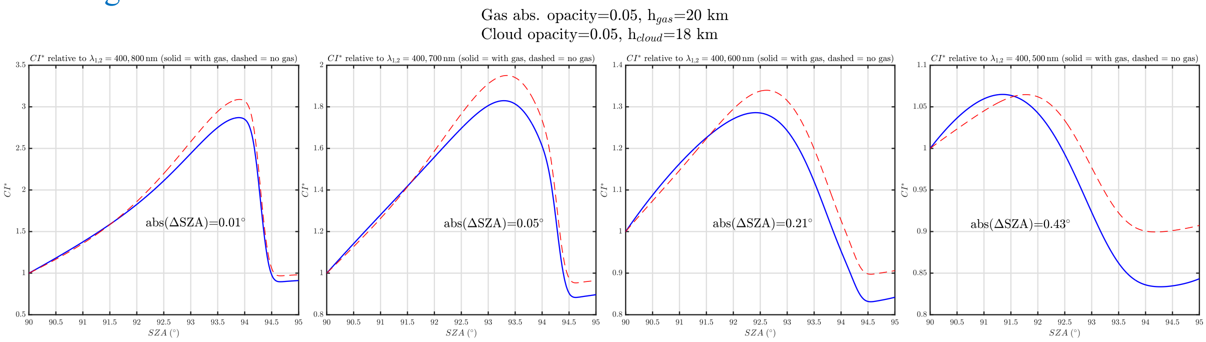

Fig.1 Simulations of the CI.

Figure 2 presents the same set of simulations but for a total gaseous absorption optical depth of 0.02. As expected, the impact of gaseous absorption is reduced. Nevertheless, the same general trend is observed: the smaller the spectral separation between the two wavelengths, the larger the effect on the retrieved SZAmax. Consequently, an inaccurate representation of gaseous absorption may introduce errors in the retrieved cloud altitude. This also provides additional motivation for the proposed single-wavelength methodology, which avoids the need to optimize the selection of two wavelengths while simultaneously reducing the influence of wavelength-dependent gaseous absorption.

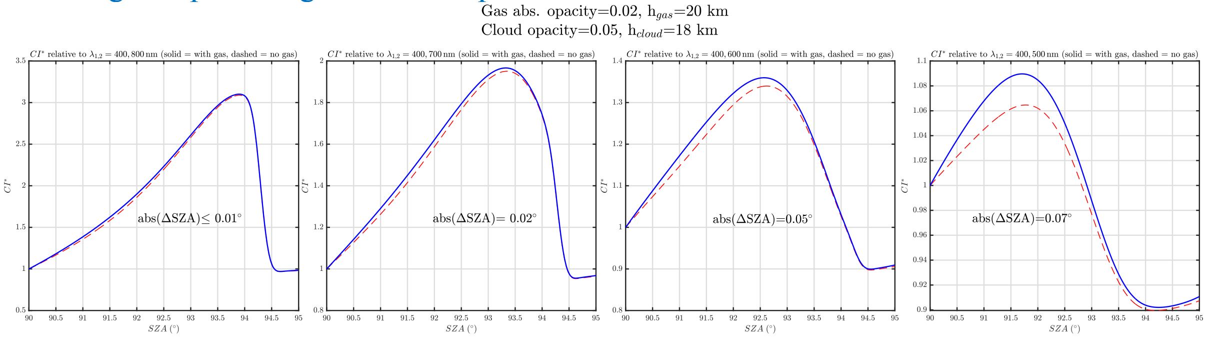

Fig.2 Simulations of the CI.

We have also considered including these additional sensitivity tests in the manuscript. However, since one of the main recommendations from the reviewers was to better emphasize the main contributions, we considered that adding several additional figures and a detailed discussion of the influence of gaseous absorption would unnecessarily increase the length and complexity of the manuscript. Instead, we have added a a text summarizing these results and clarifying the expected impact of gaseous absorption on the retrieval. In particular, the following text has been added in Section 3.4, immediately after "...an inaccurate representation of such temporal cycles may lead to significant errors in the retrieved cloud altitude.":

'To illustrate this point, we performed a series of sensitivity tests considering a Gaussian absorbing layer centred at 20 km, with a geometrical thickness of 10 km, and a total absorption optical depth ranging from 0.01 to 0.1 at λ1 = 400 nm, , while assuming negligible gaseous absorption at λ2. These calculations were not intended to reproduce a particular atmospheric absorber, but rather to provide a generic test case for investigating the influence of gaseous absorption on CI-based cloud-height retrievals. The simulations show that the displacement of SZAmax generally increases as the spectral separation between the two wavelengths decreases. For example, for a cloud located at 18 km and an absorption optical depth of 0.05, the maximum displacement reached approximately 0.43◦for the 400/500 nm wavelength pair, corresponding to an error of about 2 km in the retrieved cloud height. This value should not be regarded as universal, since the impact depends on the selected wavelengths, the cloud altitude, and the optical depth and vertical distribution of the absorbing species. To mitigate these modelling uncertainties, one possible approach is to select λ1 and λ2 outside the main absorption bands of the gases present, thereby simplifying the RT modelling.'

-The manuscript contains a number of valuable contents, but the main achievements – namely, the mechanistic explanation of the CI maximum and the derivation of a new single-wavelength formalism for detecting high-altitude clouds – get a little bit lost in the overall length and technical depth. I recommend overthinking the paper's structure to better highlight these novel findings. Consider shortening the more mathematical sections in the first half of the manuscript or moving the detailed derivations to an appendix.
*Author response: We thank the reviewer for this suggestion. In the revised manuscript, Section 2 has been shortened to improve the overall balance of the paper and place greater emphasis on the new single-wavelength methodology. In particular, Fig.~1 and its associated discussion have been removed, and several introductory explanations have been condensed. Regarding the mathematical derivations, we believe that, given the strong methodological focus of the manuscript, moving part of the derivations to an appendix would interrupt the flow of the presentation and make it more difficult for the reader to follow the development of the new formalism. For this reason, we have considered it more appropriate to retain the main derivations in the body of the manuscript.
-Finally, the conclusions would benefit from a broader outlook. How does the proposed Rayleigh-referenced CI advance our understanding of high-altitude cirrus and polar stratospheric clouds compared to previous approaches?
*Author response: To provide a broader outlook on the implications of the proposed methodology, the following sentence has been added at the end of the second conclusion, where the Rayleigh-referenced CI is introduced:

'Consequently, the proposed Rayleigh-referenced CI provides a more flexible framework for future studies of optically thin high-altitude clouds, including cirrus and polar stratospheric clouds, using a broader range of observing systems.'

Specific comment and technical corrections

-l. 22: “Clouds play a major role in Earth climate system” -> “Clouds play a major role in the Earth’s climate system”
*Author response: Corrected.
-l. 35: “heterogeneous reaction that provide” -> “heterogeneous reaction providing”
*Author response: We thank the reviewer for the comment. However, the sentence in the current manuscript reads "which provide surfaces for heterogeneous reactions that release reactive chlorine and bromine species that subsequently participate in catalytic ozone destruction cycles." We believe that this construction is grammatically correct, with the relative clause referring to "heterogeneous reactions". Therefore, we have retained the original wording.
-l. 119: Please rephrase the sentence to avoid misunderstandings regarding “the transition above (?) which the atmosphere no longer receives direct illumination.”
*Author response:
-l. 165: Remove parentheses around the citation: (Toledo, 2016) -> Toledo (2016)
*Author response: Done.
-l. 171: It appears that P (not P_total) is shown in the figures. Please revise the corresponding text accordingly.
*Author response: The reviewer is correct. The figures show P, rather than Ptotal, and the corresponding text has been corrected accordingly.
-l. 259: Remove parentheses: (see, e.g., (Gomez-Martin et al., 2021)) -> (see, e.g., Gomez-Martin et al., 2021)
*Author response: Done.
-l. 325: “at lower SZA<95°” -> “at SZA below 95°”
*Author response: Corrected.
-l. 366/367: For improved readability, move the phrase “as will be discussed in the following sections” to the end of the sentence.
*Author response: Done.
-l. 422: Briefly define “droxtals”.
*Author response: A brief definition of droxtals has been added when the term is first introduced in the manuscript.
-Fig. 1: Please specfy the resulting optical thickness of the cloud layer considered.
*Author response: Following the recommendation of Reviewer #1 to simplify Section 2 and improve the focus of the manuscript, Fig. 1 has been removed from the revised version. Consequently, this comment is no longer applicable.
-Fig. 2: The small inset in the top-left corner of panel (a) is not referenced in the caption or main text. Consider removing it for clarity, or integrate the zenith angle directly into the Sun’s ray depiction.
*Author response: The inset has been retained because it provides a clear definition of the solar zenith angle, which is used throughout the manuscript. However, the caption has been revised to explicitly describe the inset.
-Fig. 5: Use a consistent color scheme for the 450 nm and 950 nm results in both panels. Consider using black or a third color for CI* in the right panel.
*Author response: Thank you for the suggestion. In panel (b), the blue and red colours were intentionally chosen to match the left and right vertical axes, respectively, thereby facilitating the association between each curve and its corresponding axis. For this reason, the original colour scheme has been retained.

-Fig. 6: The wavelengths listed in the caption do not match those shown in the left panel. Additionally, no results are displayed for the transition region between 550 and 700 nm. Please either include data for these wavelengths or justify the exclusion of 600 and 650 nm.
*Author response: The figure caption has been corrected to include all wavelengths displayed in panel (a). Regarding the second point, the results at 600 and 650~nm have not been included because they follow the smooth spectral evolution observed between the neighbouring wavelengths (550 and 700~nm) and therefore do not provide additional qualitative information. To clarify this point, the following sentence has been added to the manuscript:
"*The results at 600 and 650nm have been omitted for clarity, as they follow the smooth spectral evolution observed between the neighbouring wavelengths (550 and 700nm) and therefore do not provide additional qualitative information.*"
-Fig. 7: The study by Lauster et al. (2022) has been referenced earlier. For completeness, consider including the corresponding CI ratios from that work.
*Author response: The wavelength pairs used by Lauster et al. (2022) to compute the CI have now been added to Fig.6 of the revised manuscript as dashed vertical lines.
-Fig. 10 + 11: It may be helpful to add the value of SZA_max for better visual orientation, similar to Fig. 9.
*Author response: In the revised manuscript, vertical dashed lines indicating the value of SZAmax have been added to Figures 10 and 11 (9-10 of the revised manuscript). In addition, the figure captions have been revised to explicitly state that the reported values of SZAmax were obtained assuming $\lambda 1$=400 nm in each case.