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A proposal for improved colorbars for cloud and aerosol lidar parameters

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Abstract: Currently, there are still many scientific publications showing lidar curtain images that are plotted with colormaps, such as the rainbow or jet, that poorly represent the data because they distort the information through non-linear changes in the perceived lightness. Those colormaps are also very difficult to interpret for people affected by a color-vision deficiency, which affects around 1 in 12 men and 1 in 200 women. Based on growing demand for accessibility, scientific journals are now making color-vision deficiency accessibility a priority as part of the submission requirement. Here we propose a set of colorblind-friendly colormaps for atmospheric lidar observations associated with cloud and aerosol studies.

1. Introduction

Currently, there are still many scientific publications showing lidar curtain images that are plotted with colormaps, such as the rainbow or jet, that poorly represent the data because they distort the information through non-linear changes in the perceived lightness. Those colormaps are also very difficult to interpret for people affected by a color-vision deficiency (CVD) [1], which affects around 1 in 12 men and 1 in 200 women. In fact, as noted by Wong (2011) [2]: "*If a submitted manuscript happens to go to three male reviewers of Northern European descent, the chance that at least one will be color blind is 22 percent.*". Based on growing demand for accessibility, scientific journals are now making CVD accessibility a priority as part of the submission requirement.

Here we propose a set of colorblind-friendly colormaps for atmospheric lidar observations associated with cloud and aerosol studies. One way to achieve colorblind-friendly colormaps is to ensure that the perceived lightness increases sequentially. Such perceptually-sequential colormaps (Fig. 1) are not only useful for colorblind people but have been shown to better represent the data for normal-vision beholders. In fact, Borkin et al. (2011) [3] have shown that a perceptually appropriate colormap leads to fewer heart disease diagnostic mistakes than a rainbow color map.

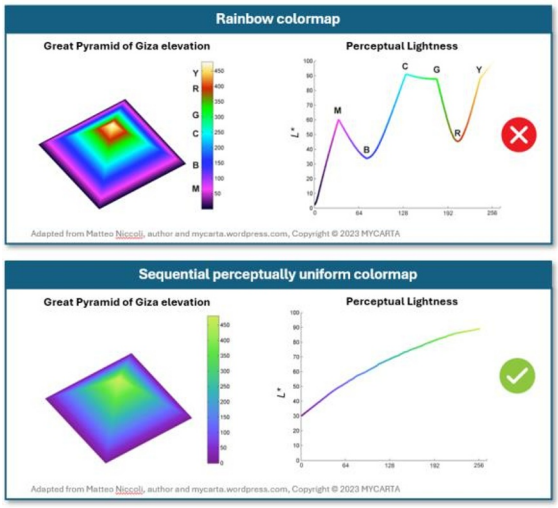

Figure 1. Elevation of the Great Pyramid of Giza color-coded with a rainbow colormap (top) and a perceptually-sequential colormap (bottom).

2. Method

When defining the new colorbars, the main goals are to ensure perceptually uniform changes in lightness, to use color combinations that are CVD friendly, and to allow visual quantification of the displayed variable. Depending on the variable, many more secondary objectives could be added, and compromises needed to be made (Fig. 2). The colormaps proposed by this effort aim to strike a balance between these goals for the most common analysis tasks for lidar imagery.

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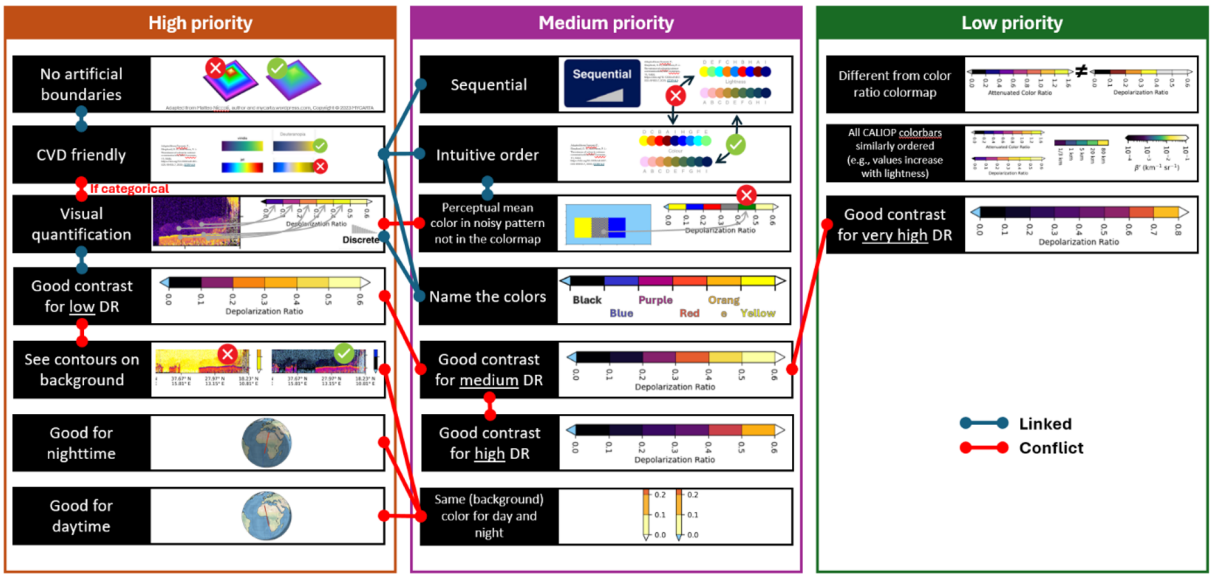

Figure 2. Priority list for the derivation of a new colorbar for depolarization ratio.

3. Colormaps proposal

For now, colormaps are proposed for backscatter, color ratio, and depolarization ratio parameters. The colormaps were defined using space lidar observations of CALIOP. Defining colorblind-friendly colormaps on such observations are very challenging for two reasons. First, space lidar observations are very noisy, generating images with high variations at a pixel level. This effect can be even amplified when looking at ratios of lidar properties. Second, attenuated backscatter signal spreads over multiple orders of magnitude. The proposed colormaps accommodate these challenges to yield colorbars that are colorblind-friendly and are adaptable to lidar systems with higher SNR.

Figure 3 shows a comparison of the depolarization ratio colorbar currently used for the online CALIOP browse images (https://www-calipso.larc.nasa.gov/products/lidar/browse_images/production/) and proposed colorbars derived from the priority list (Fig. 2). Figure 4 shows the same plots as perceived by people with deuteranopia CVD. In the current colorbar, it appears clearly on the CVD simulation (Fig. 4) that some colors of the colorbar can be

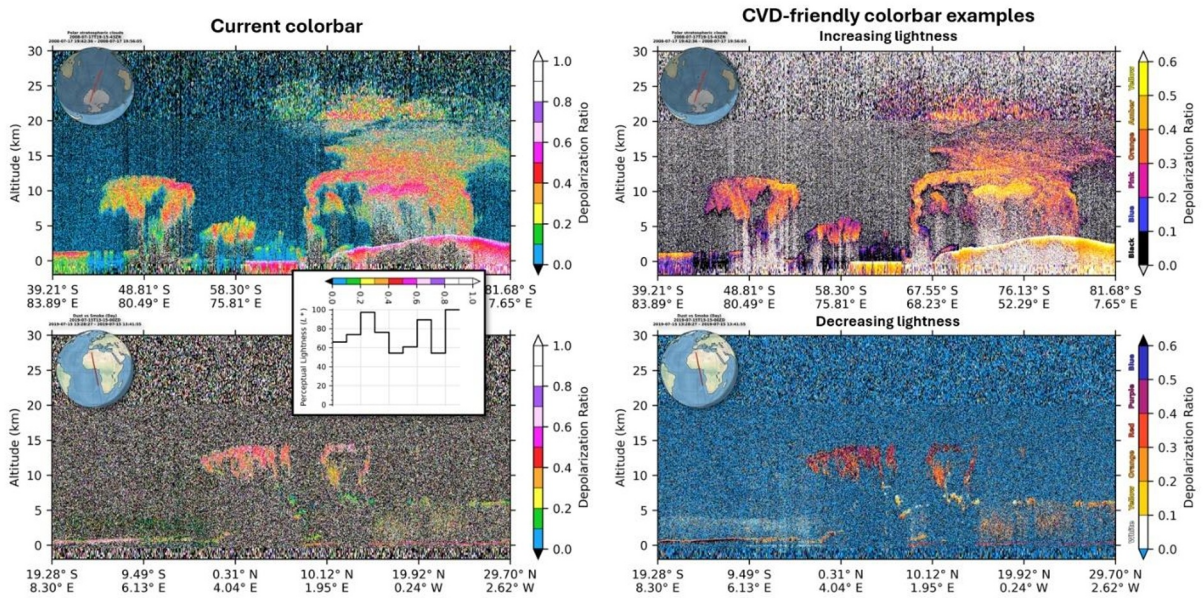

Figure 3. Comparison of the current depolarization ratio colorbar (left) and new proposals (right) for a nighttime (top) and a daytime (bottom) case studies.

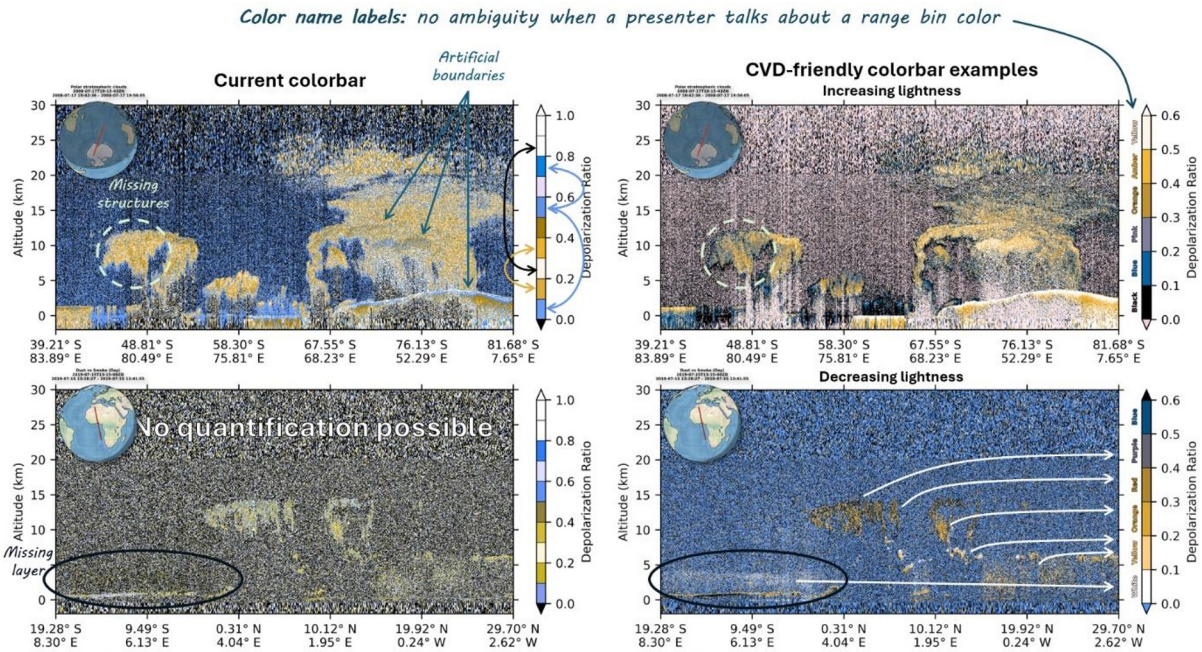

Figure 4. Fig. 3 as perceived by people with (deuteranopia) color-vision deficiency.

confused by CVD people. Because the lightness is not sequential, it generates artificial boundaries and some structures are missed. The proposed colorbars solved those issues and allows to quantify the depolarization ratio of the different patterns and quickly found the high and low values.

Figure 5 shows a comparison of the color ratio colorbar currently used for the online CALIOP browse images and a new proposal. The new colorbar helps to solve similar problems than those identified with the depolarization ratio colorbar (Figs. 3 and 4).

Figure 6 shows a comparison of the attenuated backscatter colorbar currently used for the online CALIOP browse images and a new proposal. Here, because the signal spreads over multiple orders of magnitude a multi-sequential colormap is chosen. The proposed colormap mimics the current colormap but removes the green colors to avoid CVD confusion with red colors. A continuous colorbar is chosen to allow to see small gradient variations and because a discrete colorbar would not help making visual quantifications due to the too large number of bins required to represent all the range of possible values. The colorbar is also extended down to 10^{-5} using dark blues. It allows to see very faint layers which is particularly useful in the perpendicular channel (Fig. 6b).

4. Perspectives

A critical objective of presenting this effort to the ILRC is to get feedback from the atmospheric lidar science community to potentially converge to common set of colormaps for the commonly used atmospheric lidar variables as was done in the ocean science community [4]. We hope that such common set of colormaps would be a useful tool for the satellite lidar community (CALIPSO, CATS, ACDL, ATLID, ICESat, and future missions).

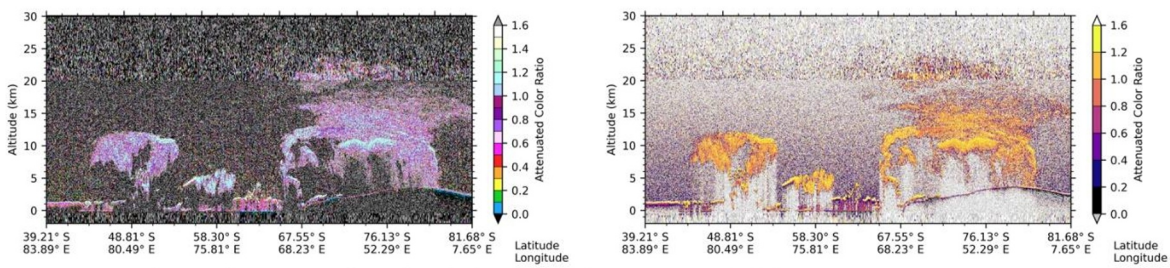

Figure 5. Comparison of the current color ratio colorbar (left) and a new proposal (right).

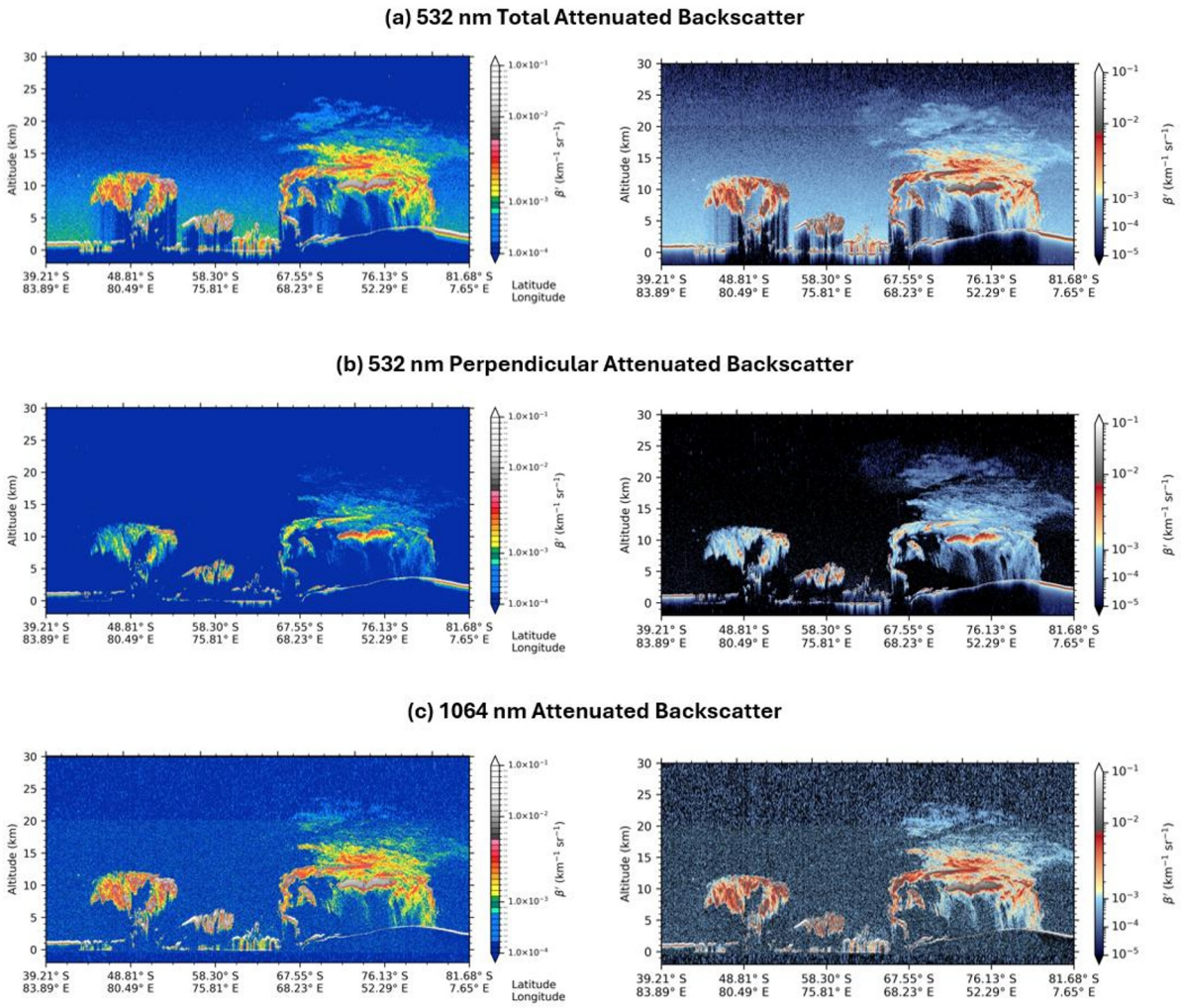

Figure 6. Comparison of the current color ratio colorbar (left) and a new proposal (right).

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