AN INITIAL ASSESSMENT OF THE CALIPSO AEROSOL SUBTYPING ALGORITHM

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ABSTRACT

The Cloud Aerosol Lidar Infrared Pathfinder Satellite Observations (CALIPSO) with its 3-channel lidar affords observations that can, with minimal processing, be exploited to identify aerosol types. Three months of CALIPSO Level II data are analyzed to assess the veracity of the CALIPSO aerosol type identification algorithm and generate distributions of aerosol types and their respective optical characteristics. The distributions show that the classification algorithm has no (1) surface type or (2) diurnal dependencies. For this initial assessment of algorithm performance, we analyze global distributions of the CALIPSO aerosol types, along with distributions of integrated attenuated backscatter, backscatter color ratio, and volume depolarization ratio for each type. The aerosol type distributions are further partitioned according to various geophysical discriminators (e.g., geographic region, land vs. ocean, and day vs. night). The algorithm generates expected results in most scenes with few cases of thin clouds classified as aerosols and subsequently typed as 'dust' or 'smoke'[1]. The total color ratio distributions show significant overlap between the aerosol types

1. INTRODUCTION

Aerosol classification has several purposes: attribution of aerosol radiative forcing to natural or anthropogenic emissions requires the determination of the source of the aerosol; aerosol radiative properties vary significantly by type; and, most directly, determination of aerosol type allows an estimate of extinction-to-backscatter ratio (S_a). By "type" we mean an aerosol mixture which is characteristic of a region or an air mass. The mixture observed at a given location depends on the local and remote aerosol sources and wind trajectories, internal and external mixing, the state of hydration, and chemical processes which may have occurred during transport. In the CALIPSO classification scheme, each aerosol type is assumed to be a mixture of different species, where the mixing can be internal, external or both. The underlying paradigm is that the variety of emission sources and atmospheric processes will act to produce airmasses that can be characterized as consisting of a single, generic aerosol "type". This is an idealization, but one that allows us to classify aerosols based on observations and location, and thus gain insight into the geographic distribution of aerosols and constrain the possible values of extinction-to-backscatter ratios for use in the CALIPSO aerosol extinction retrievals.

2. AEROSOL MODELS

The CALIPSO models define six aerosol types: desert dust, biomass burning, background, polluted continental, marine and polluted dust. These models were derived in part from a global cluster analysis of a multi-year AERONET database of aerosol properties [2]. The classes so derived are hereafter referred to as AERONET clusters. While this set does not cover all possible aerosol mixing scenarios, it accounts for a majority of mesoscale aerosol layers. In essence the algorithm trades off complex transient multi-component mixtures for relatively stable layers with large horizontal extent (10-1000 km). After discriminating cloud and aerosol layers, the Scene Classification Algorithm (SCA) attempts to identify the type of aerosol in the layer. If the type identification is successful, a look-up table is used to associate a lidar ratio and other properties with that layer. Since the AERONET records of the background aerosols have low mean optical depths (generally < 0.05 at 673 nm), the microphysical properties derived from these are likely to have large uncertainties [3]. The CALIOP background aerosol model was derived by fitting size distributions and refractive indices to measurements of S_a of long-range continental transport [4] and to generate an S_a value of 35 sr. Note that the S_a value for this aerosol type is used to generate the approximate extinction product described above. Similarly, the AERONET marine aerosol cluster is comprised of a small number of records (< 4% of the total). This dearth of marine aerosol data renders the AERONET marine cluster unrepresentative. The CALIOP marine aerosol model is derived from the parameters measured during the SEAS experiment [5]. Polluted dust accounts for episodes of mixed dust and biomass burning smoke which are frequent in regions close to strong sources of both types, for example in West Africa (*cf.* MODIS images) and Asia (*cf.* ACE-Asia, INDOEX). The CALIOP polluted dust model is a mixture of the AERONET desert dust (coarse mode) and biomass burning (fine mode) clusters. The smoke (also referred to as biomass burning) cluster of AERONET measurements is used to model the CALIOP smoke aerosol.

3. METHODS

We investigate the distributions optical properties of the layers found at the highest resolution. To identify aerosol features at their finest resolution, the CALIPSO feature finding algorithm makes several passes through a specified scene, successively increasing the horizontal averaging distance from 5 km, to 20 km, to 80 km. For this study, we analyse only the strongest features, i.e., those found at 5 km. Using level II CALIPSO lidar data, i.e., we examine distributions of the integrated attenuated backscatter ($\gamma'_{feature}$), where

$$\gamma'_{feature} = \int_{top}^{base} \beta_p(\mathrm{r}) \cdot T_p(\mathrm{r})\, d\mathrm{r} \qquad (1)$$

β_p and T_p are the aerosol backscatter and transmission, respectively. Though not always an indication of the optical depth, it is a good indicator of the amount (particle number concentration) of aerosol in the layer. The volume depolarization ratio (δ_{layer}), is defined as,

$$\delta_{layer} = \frac{\int_{top}^{base} \beta_{\perp}(\mathrm{r})\mathrm{r}}{\int_{top}^{base} \beta_{\parallel}(\mathrm{r})\mathrm{r}}, \qquad (2)$$

where the subscripts $\perp$ and $\parallel$, denote perpendicular and parallel components of the 532 nm backscatter. δ_{layer} is a good indicator of the relative proportion of non-spherical particles of the aerosol mixture.

The total color ratio (χ') defined as

$$\chi' = \frac{\int_{top}^{base} \mathrm{B}_{1064}(\mathrm{r})\mathrm{r}}{\int_{top}^{base} \mathrm{B}_{532}(\mathrm{r})\mathrm{r}}, \qquad (3)$$

is a ratio of the integral of the 1064-nm backscatter to the integral of 532 nm backscatter within the layer. χ' is a rough indicator of the dominant particle sizes in the aerosol layer. All these variables are level I parameters found upstream of the extinction products in the algorithm flow. We also show distributions of the feature optical depth ($\tau_{feature}$) as a cursory assessment of algorithm performance.

4. SUBTYPING ALGORITHM

The volume depolarization ratio(δ_v) is used to identify aerosol types that have a substantial mass fraction of non-spherical particles, e.g., a mixture of smoke and dust. The integrated attenuated backscatter (γ') used to discern instances of transient high aerosol loading over surfaces where this is not usually expected, e.g., aerosols in polar regions. The algorithm takes into consideration the high aerosol loading due smoke or dust layers over land or the ocean. Lightly loaded aerosol layers found over snow/ice/tundra regions such as Antarctica and the clean Arctic are classified as clean continental determined by the magnitude of γ'. Arctic haze, by virtue of its high integrated backscatter value, is classified as polluted continental. Desert dust is identified by δ_v greater than 0.2. Aerosols with $0.075 < \delta_v < 0.2$ are classified as polluted dust. Aerosol layers found at land surfaces identified as urban areas are classified as polluted continental. To account for continental pollution advected off the coast and entrained in the marine boundary layer, we use the elevation above the ocean surface as an additional criterion. The land/water mask is based on the World Vector Shoreline (WVS) product and the surface types are from the International Geosphere Biosphere Programme (IGBP). A detailed description of the algorithm along with flow charts can be found at http://www-calipso.larc.nasa.gov/resources/pdfs/PC-SCI-202_Part3_v1.0.pdf

5. RESULTS

Figure 1 shows the distribution of aerosol types as the satellites passes over W. Russia, continental Europe, across the Mediterranean to the eastern Sahara desert. The sub-typing algorithm captures the evolution of the aerosol from smoke and polluted dust to pure dust in the Sahara. Figure 2 is another example of the sub-typing result showing an aerosol layer that has been classified as predominantly smoke extending from land to the deep ocean. Note the aerosol type on the ocean surface is appropriately classified as marine aerosol. Figure 3 shows the descriptive statistics of γ', δv, and χ' for three months (September, October, December of 2006). Both the means and standard deviations for all the three parameters show consistent patterns of the monthly distributions. Figure 4 shows the probability distribution functions (PDFs) of **γ', δ_v, and** χ' for one month (November 2006) for dust and polluted dust cases. We have superimposed the PDFs of the land surface layers and the ocean surface layers to examine any surface dependencies. The PDFs show that there are no dependencies on surface type.

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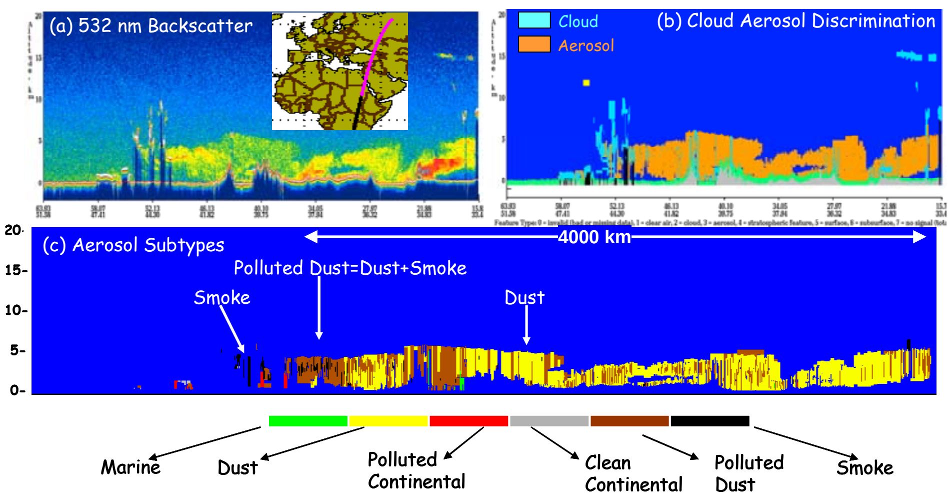

Figure 1. The evolution of aerosol types as the satellites passes over W. Russia, continental Europe, across the Mediterranean to the eastern Sahara desert from smoke to dust.

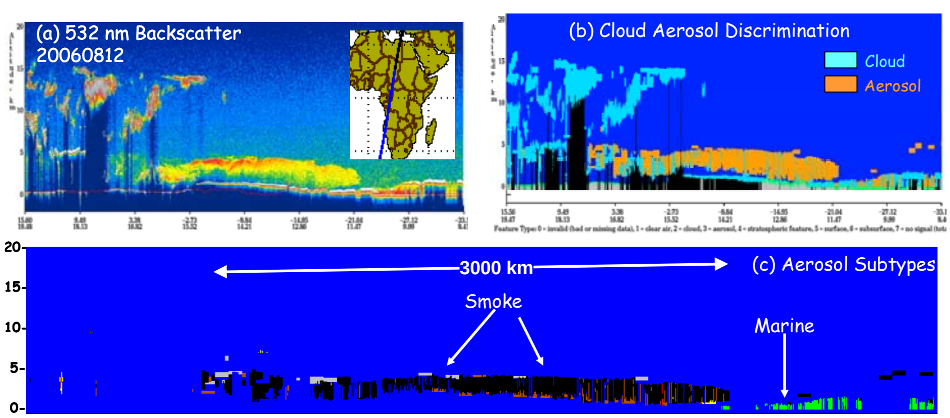

Figure 2. An aerosol layer identified by the sub-typing algorithm as smoke and polluted dust extending from Central Africa, the Congo basin, Angola to the S Atlantic Ocean (color key as in Fig 1)

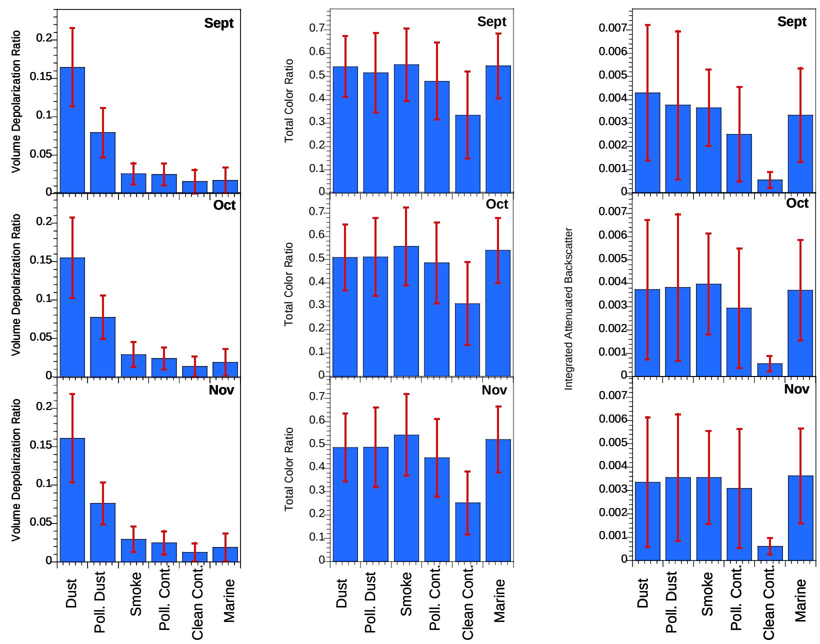

Figure 4 Means (blue bar) and Standard Deviations (Red line)of γ', δ_v, and χ' for September, October, December of 2006

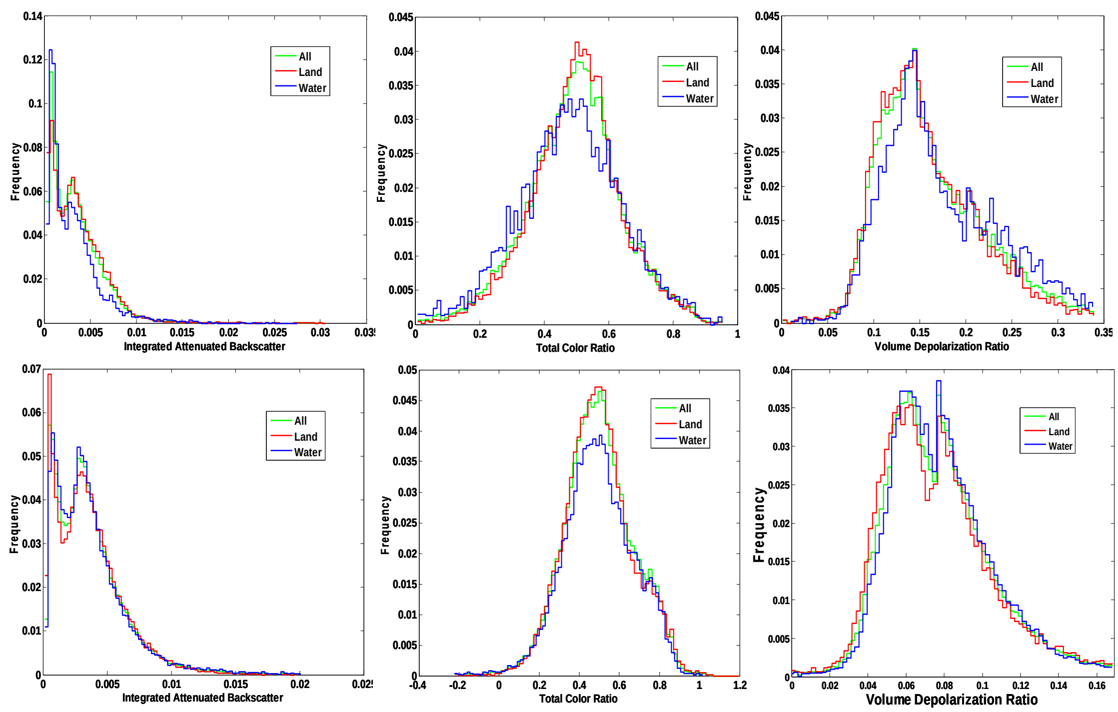

Figure 4 shows the probability distribution functions (PDFs) of γ', δ_v, and χ' for one month (November 2006) for dust and polluted dust cases. The different colors denote layers found over land (red), water (blue) and both (green).