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Comparative study of aerosol and cloud detected by CALIPSO and OMI

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ABSTRACT

Aerosol and cloud play important roles in the atmosphere and climate system. Accurately detecting their presence, altitude, and properties using satellite radiance measurements is a very important task. This paper presents a comparative analysis of the Cloud–Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) Level 2 Vertical Feature Mask (VFM) product with the Ozone Monitoring Instrument (OMI) UV Aerosol Index (UVAI) and reflectivity datasets for a full year of 2007 from regional to global scales. Based on CALIPSO and OMI observations, the vertical and horizontal extent of clouds and aerosols are determined and effects of aerosol type, load and cloud fraction on aerosol identification are discussed. It was found that the spatial–temporal correlation found between CALIPSO and OMI observations, is strongly dependent on aerosol types and cloud contamination. CALIPSO is more sensitivity to cloud and often misidentifies aerosol as cloud, while some small scale aerosol layers as well as some pollution aerosols are unidentified by OMI UVAI. Large differences in aerosol distribution patterns between CALIPSO and OMI are observed, especially for the smoke and pollution aerosol dominated areas. In addition, the results found a significant correlation between CALIPSO lidar 1064 nm backscatter and the OMI UVAI over the study regions.

1. Introduction

Dust from desert storms and smoke from biomass burning and boreal forest fires are the most predominant aerosol types [Herman and Celarier, 1997] and play an important role in the atmosphere via a number of complex processes. They can warm air masses and induce an increase or a reduction of cloud cover, depending on the vertical distribution of the aerosols within or above the clouds [Johnson et al., 2004]. Due to the importance of smoke and dust aerosols in climate, environment and air quality, detection of smoke and dust aerosols and monitoring their distribution and evolutions is an important task [Kaufman and Fraser, 1997; Torres et al., 1998; King et al., 1999; James et al., 2007].

Satellite remote sensing has been demonstrated as an effective way to monitor and study aerosols. One of main challenges of satellite aerosol remote sensing is cloud effect. Clouds reflect a part of the radiation back to space and obscure the detection of aerosols. Aerosols above clouds or with a high percentage of cloud cover are also difficult to identify. Consequently, improper cloud screening often causes the error (pixels unidentified or misidentified) in satellite-derived aerosol fields. Currently, NASA has several satellites that make up the Afternoon Constellation (A-Train) for diversities of applications. The Cloud–Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) is part of the A-Train and provides information on the vertical profile of the atmosphere including information about aerosols and clouds. The CALIPSO Lidar L1B profile provides total attenuated backscatter at 532 nm and 1064 nm and perpendicular attenuated backscatter at 532 nm [Winker et al., 2003]. The CALIPSO Vertical Feature Mask (VFM), one of CALIPSO level 2 products, classifies contiguous atmospheric regions of backscatter as different layers such as dust, smoke, cloud and clear air [Vaughan et al., 2004]. As an active remote sensing device, however, CALIPSO only makes nadir measurements, and so its global coverage is limited. On the other hand, smoke and dust events near or mixed with cloud may be misclassified by CALIPSO algorithm [Chen et al., 2010]. The Ozone Monitoring Instrument (OMI) is another sensor in the A-Train for aerosol monitoring. The OMI sensor measures the solar backscatter radiation in the ultraviolet (UV) and visible spectrum [Levelt et al., 2006]. The OMI near-UV aerosol algorithm (OMAERUV) derives aerosol properties such as UV Aerosol Index (UVAI), single scattering albedo, aerosol extinction and absorption optical depths at 388 nm [Torres et al., 2007]. The UVAI is a very useful qualitative indicator of the presence of the absorbing aerosols in the atmosphere that differentiates very well between absorbing and non-absorbing

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aerosols, because it provides a qualitative measure of absorption of UV radiation by smoke and desert dust [Herman and Celarier, 1997; Torres et al., 1998]. Positive values for the UVAI are associated with UV absorbing aerosols above the boundary layer, negative values are associated with low altitude weakly absorbing aerosol particles or small size non-absorbing aerosols [Torres et al., 1998]. The UVAI is insensitive to cloud presence yielding near zero values, and detects absorbing aerosols even when mixed with clouds or above cloud decks [Torres et al., in press]. A limitation of the OMAERUV algorithm is the need to assume the height of absorbing aerosol layers which is, therefore, a source of uncertainty in the retrieved aerosol parameters [Torres et al., 1998]. The latest version of the OMAERUV aerosol data makes use of a CALIPSO-based aerosol layer height climatology that has improved the accuracy of the retrieved aerosol optical depth [Ahn et al., 2011].

In this paper, the spatial and temporal variability of the absorbing aerosols (dust and smoke) and cloud resulting from CALIPSO and OMI observations are presented and the capabilities of CALIPSO and OMI to detect aerosols are evaluated by conducting a comparative statistic analysis of CALIPSO VFM and OMI UVAI products. Comparisons of the aerosol vertical distribution in three distinct regions are also presented.

2. Data and methods

In this study, CALIPSO Level 1B daytime backscatter data, CALIPSO level 2 Vertical Feature Mask (VFM) daytime product and a collocated subset of OMAERUV observations were used. The CALIPSO Cloud–Aerosol Lidar with Orthogonal Polarization (CALIOP) is a two-wavelength polarization-sensitive lidar that provides

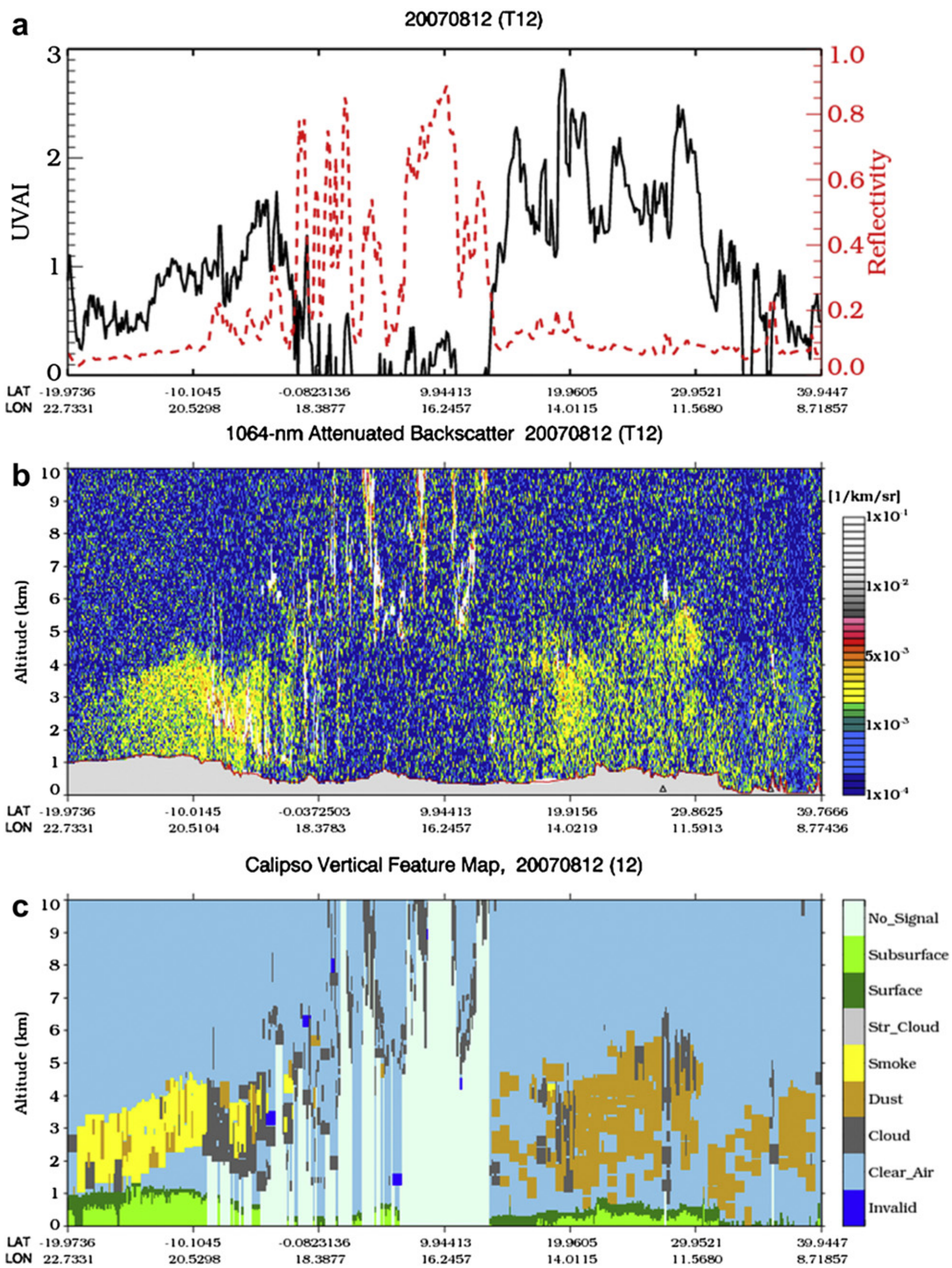

Fig. 1. Example of smoke and dust over Africa detected by OMI and CALIOP at around 12:30 UTC on 12 August 2007; (a) shows OMI UVAI (black solid line, left ordinate) and reflectivity (red dashed line, right ordinate); (b) shows CALIOP 1064-nm attenuated backscatter; and (c) shows CALIOP Vertical Feature Mask (VFM). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)