CORRELATION, VERTICAL DISTRIBUTION AND COLUMN INTEGRATED CHARACTERISTICS OF AEROSOLS DURING WINTER-TIME DUST STORMS OVER THE MEDITERRANEAN REGION

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ABSTRACT

A synergistic combination of space based sensors for vertical and column integrated measurements of aerosol parameters is providing opportunities for a detailed and systematic analysis of vertical structure and characteristics of dust storms from sources to sinks. As an integral part of Afternoon-train (A-train), the column measurement of aerosols by MODIS Aqua is followed by vertical as well as column integrated measurements of aerosols by CALIPSO within 1-2 minutes (during daytime overpass). The vertical profiles as well as column integrated values of aerosols from Aqua (level-2, 10 km grid, collection 5.1) have been derived along the CALIOP (onboard CALIPSO platform) line of path for the best achievable spatial collocation for correlation and sensitivity analysis. The night-time CALIOP derived column integrated AOD and day-time deep blue AOD from Aqua (for the dust storm event on February 5, 2009) show good correlation (R^2 = 0.88), while dark target AOD data from Aqua show poor or no-correlation over the land region (Sahara desert). The Aqua dark target AOD (land and ocean) product shows moderate correlation (R^2 = 0.48) with CALIOP column integrated AOD over the ocean. The low correlation over the sea could be partially attributed to the temporal difference between night-time CALIOP and day-time MODIS measurements. The CALIPSO derived parameters (AOD and Backscatter) are sensitive to varying concentration of aerosols in the dust storm (25-35^{0}N, AOD ranges 0.1-0.9, and IAB ranges 0.010 to 0.019 sr) and clouds (IAB ranges > 0.02 – 0.1 sr). The fine, mixed and coarse aerosols (derived from MODIS) show distinct relationship and range of sensitivity to CALIPSO derived parameters (Column AOD_{532nm} and IAB at 532nm).

1. INTRODUCTION

A major winter-time dust storm affected the Mediterranean region during February 5, 2009 (Kaskaoutis et al., 2012). Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) nighttime overpass detected the vertical structure of this dust storm around the coast of Libya with footprint passing through Niger, Libya, Mediterranean Sea, and Europe (Figure 1a). The spatial extent of the dust storm is measured by daytime overpass of Moderate-resolution Imaging Spectroradiometer (MODIS) aqua. The nighttime CALIPSO derived column AOD and column integrated attenuated backscatter (IAB) show peaks around the coast of Libya (Figure 1b, c). The detailed observations for this dust storm as obtained from MODIS Aqua, CALIPSO daytime and night-time vertical profiles, Ozone Monitoring Instrument (OMI) Aura, and dust model DREAM are covered in Kaskaoutis et al., 2012. In this study, we have analyzed the correlation and sensitivity of MODIS and Cloud-Aerosol Lidar with Orthogonal Polarisation (CALIOP) derived aerosol parameters along the line of pass of CALIPSO during a major dust storm. The performance of deep blue and dark target AOD over the land (Sahara desert) and ocean (Mediterranean Sea) is analyzed in conjunction with CALIOP derived column integrated AOD. The range of sensitivity of MODIS and CALIOP derived parameters to fine, mixed, and coarse aerosols have been discussed.

2. DATA USED

We have used MODIS Aqua retrievals for both dark target (DT) and the deep blue (DB) algorithm during a rare wintertime dust storm over Sahara and Mediterranean Sea on February 5, 2009. We have also obtained CALIOP derived aerosol parameters (column as well as vertical structure) values for the early morning hours (00:57 to 01:03 local time) of the same day. The MODIS aerosol parameters (level-2, 10 km spatial resolution, collection 5.1) have been derived along the CALIPSO line of path for the best achievable spatial collocation. The uncertainty of MODIS aerosol observations (both deep blue and dark target algorithm) have been documented by several researchers (Remer et al. 2005, Prasad and Singh, 2007; Levy et al., 2007;

Hsu et al., 2006). The CALIOP onboard CALIPSO provides vertical structure of the atmospheric aerosols and clouds (Chen et al., 2010, Prasad et al., 2011, Rogers et al., 2010).

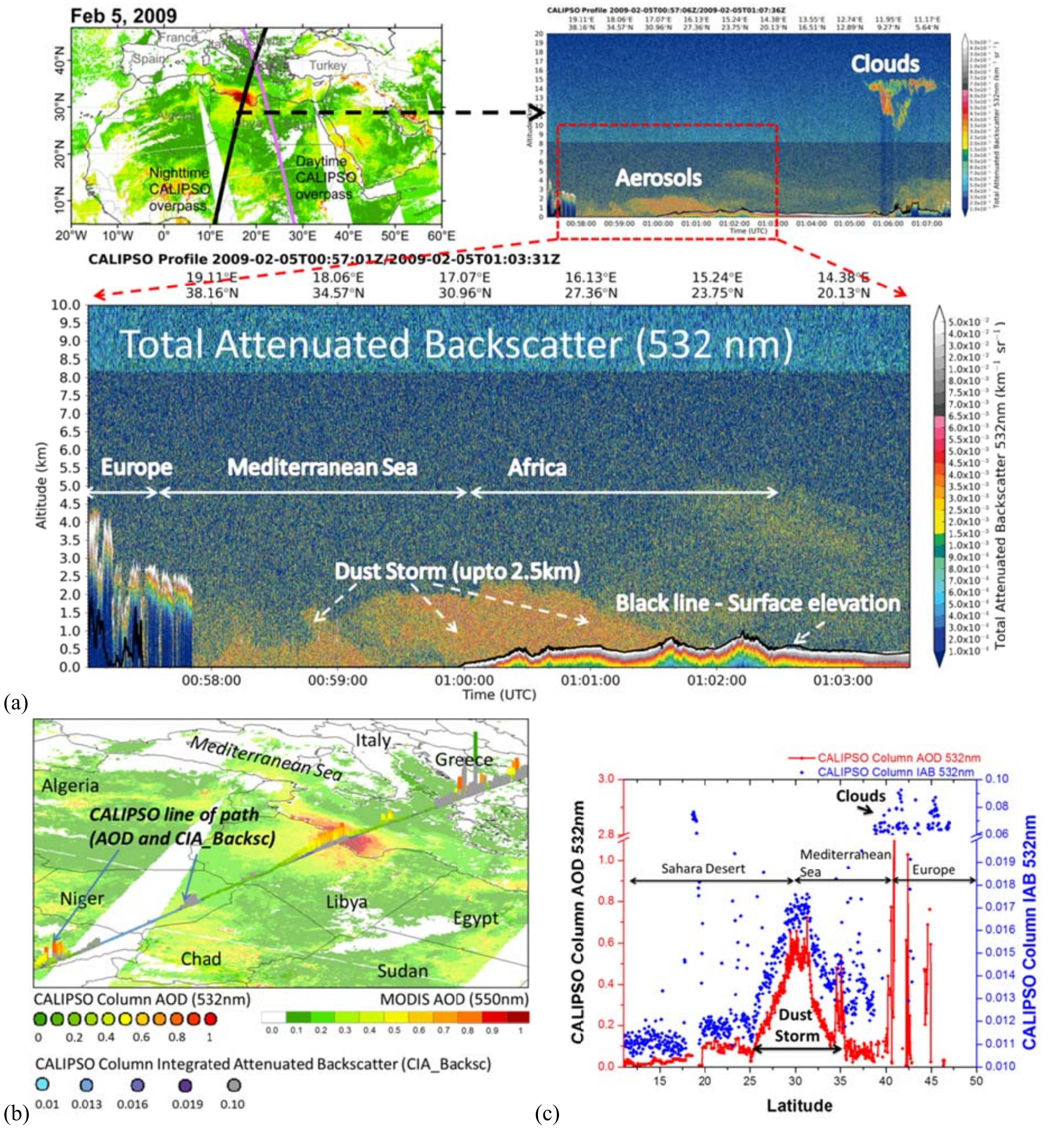

Figure 1. (a) A major wintertime dust storm around the coast of Libya was observed by MODIS Aqua and CALIOP overpass over the Mediterranean region on February 5, 2009. The vertical profile of the atmosphere (total attenuated backscatter at 532 nm) is shown along the line of path of CALIOP (thick black line running N-S). (b) The background is Aqua-MODIS Level 2 AOD (10 km grid) spatial distribution over Sahara and Mediterranean regions on 5 February 2009. The vertical bars are nighttime CALIOP overpass derived column AOD_{532} and column integrated attenuated backscatter (IAB) values for the early morning hours (00:57 to 01:03 localtime) on the same day. (c) A column AOD and IAB values indicates that a major dust storm is visible between ~25-36º N latitude over the coast of Libya and Mediterranean. The clouds, distinguished by very high IAB values, are visible between ~39-47º N latitude over Europe.

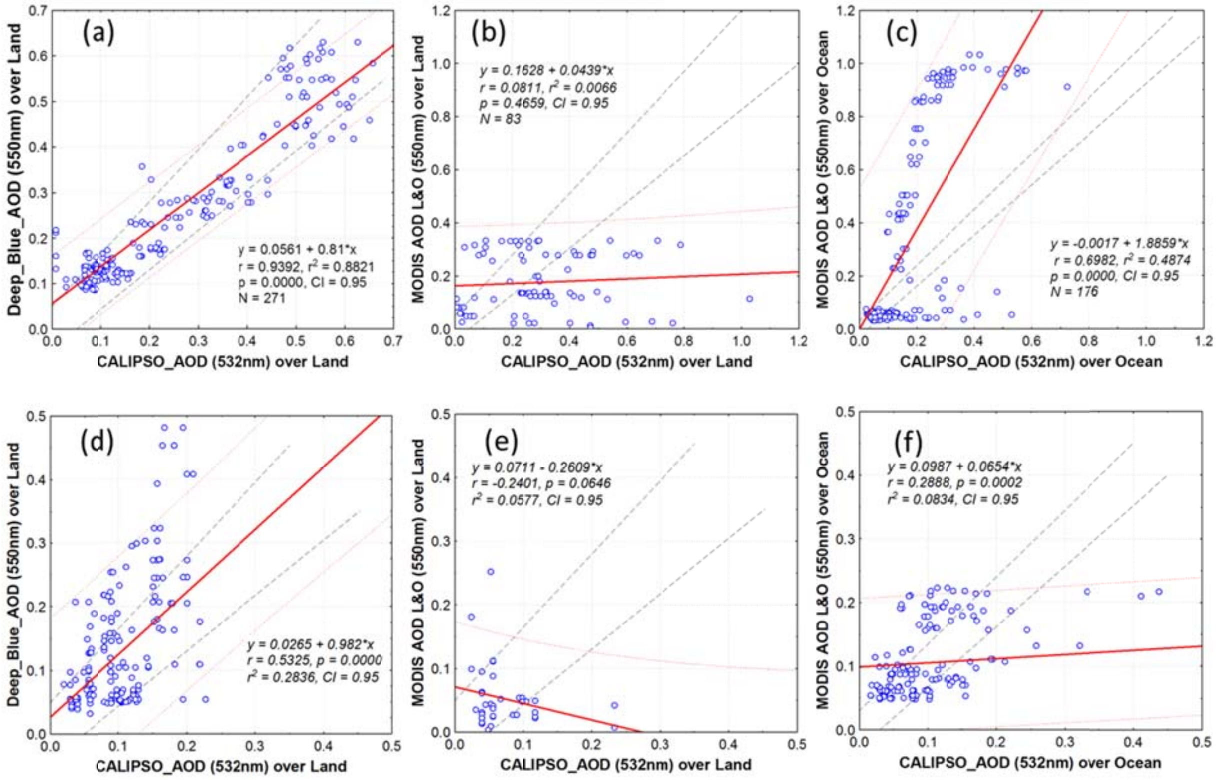

Figure 2. (a,b,c) The correlation between column integrated AOD derived from CALIPSO (532nm) during night-time with MODIS Aqua (DB AOD and DT AOD Land_and_Ocean, day-time). (d,e,f) The correlation between column integrated AOD derived from CALIPSO (532nm) during day-time with MODIS Aqua (DB AOD and DT AOD Land_and_Ocean, day-time) along the CALIPSO line of path (separately over land and ocean). The black dotted line show expected range of error in the AOD measurements from MODIS over the land and ocean (*Remmer et al.,* 2005). The red dotted line show predicted interval (at 95% CI) for linear fit (solid red line).

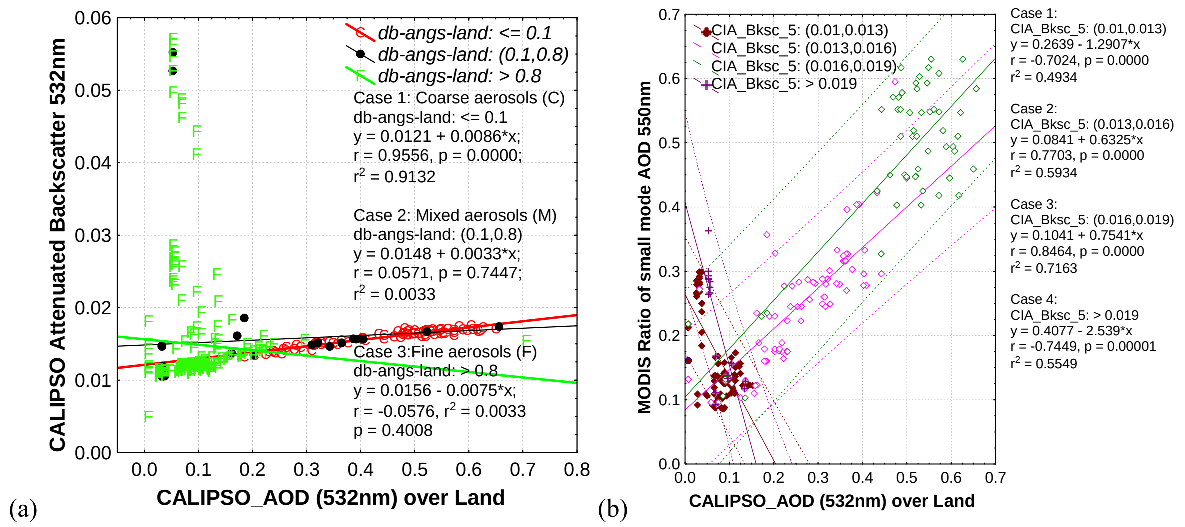

Figure 3. (a) The observed relationship (range) and sensitivity between CALIPSO derived column integrated AOD_{532nm} and attenuated backscatter (at 532nm) for coarse, mixed and fine aerosols. (b) The observed relationship between CALIPSO AOD_{532nm} and MODIS derived small mode AOD_{550nm}. The fine, mixed, and coarse aerosols show corresponding IAB range.

3. SUMMARY AND CONCLUSIONS

3.1 Column AOD and Attenuated Backscatter:

The dust storm was observed by nighttime CALIPSO overpass over the Sahara desert (Libya) and the Mediterranean Sea. The column AOD at 532 nm from CALIPSO, along the line of overpass, increases gradually from <0.1 (clean atmosphere) and ranges between 0.1-0.9 over dust storm region. Similarly, the integrated attenuated backscatter (IAB) show a gradual increase from ~0.011s and ranges between 0.011 – 0.019 s over the region of dust storm. The peak of AOD is at the center region of the dust storm, at approximately 30^0N (coast of Libya, Figure 1) which coincides with the peak of column IAB at 532nm. Figure 1c clearly shows that the nighttime column IAB is sensitive to the concentration of dust in the atmosphere and thus follows the AOD closely from non-dust (0-25 ^{0}N) to dusty region (25-35 ^{0}N). The cloudy region (39-47 ^{0}N), as expected, is marked by strong increase in the column backscatter (range >0.02-0.1 s) and thus distinguish cloudy regions over Europe from dusty regions around the coast of Libya (Figure 1c). At the peak region (column AOD = 0.4-0.9), the column IAB varies between 0.014-0.019. The column AOD and column IAB from nighttime CALIPSO overpass is found to vary linearly over the dusty and non-dusty (cloud free) regions (Figure 1c), thus help in identification of dusty regions during night-time.

3.2 Correlation between MODIS and CALIOP AOD

Night-time CALIOP derived AOD_{532nm} show good correlation (R^2 = 0.88) with DB AOD_{550nm} from MODIS Aqua over land region. However, MODIS DT AOD_{550nm} show poor or no correlation (R^2 = 0.0066) with CALIOP derived AOD_{532nm} over bright surfaces (arid land). Over ocean, CALIOP derived AOD_{532nm} show moderate correlation (R^2 = 0.48) with DB AOD_{550nm} from MODIS Aqua (Figure 2a,b,c). Due to noise in the CALIOP data during daytime measurements, the CALIOP AOD data show relatively poor correlation (R^2 = 0.28) despite near simultaneous measurements with Aqua (within 1-2 minutes) (Figure 2d). Thus, nighttime CALIOP measurements resolve the vertical structure of aerosols better than the daytime overpass.

3.3 Sensitivity: CALIPSO column AOD and IAB

Figure 3a shows range of CALIPSO derived AOD and IAB for coarse (DB Angstrom Exponent, AE ≤ 0.1), mixed (DB AE, 0.1-0.8) and fine aerosols (DB AE ≥ 0.8). The fine aerosols, from non-dusty regions over Sahara, show low AOD values (<0.25) with wide range of IAB (0.005-0.06 s). The coarse aerosols (CALIOP AOD, 0.2-0.7) show very small range of variation of IAB (within 0.014-0.018 s). Figure 3b shows the range of variation of ratio of small mode AOD from MODIS Aqua and CALIPSO AOD for four groups of IAB values. The clustering of points, for different IAB ranges, demonstrates the range of sensitivity of CALIPSO AOD and MODIS fine mode fraction.

ACKNOWLEDGEMENTS: We are grateful to MODIS (Terra, Aqua) and CALIOP science teams for providing the data. We are grateful to SSAI for financial support through grant SSAI # 2804-09-024.

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