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Supporting Information for

# First mapping of monthly and diurnal climatology of Saharan dust layer height over the Atlantic Ocean from EPIC/DSCOVR in deep space

Zhendong Lu[1], Jun Wang[1,2*], Xi Chen[2], Jing Zeng[2], Yi Wang[2,3], Xiaoguang Xu[4], Kenneth E. Christian[5,6], John E. Yorks[5], Edward P. Nowottnick[5], Jeffrey S. Reid[7], Peng Xian[7]

[1]Interdisciplinary Graduate Program in Informatics, The University of Iowa, Iowa City, IA, United States

[2]Department of Chemical and Biochemical Engineering, Center for Global and Regional Environmental Research and Iowa Technology Institute, The University of Iowa, Iowa City, IA, United States

[3]Now at Key Laboratory of Regional Ecology and Environmental Change, School of Geography and Information Engineering, China University of Geosciences, Wuhan, China

[4]GESTAR-II and Department of Physics, University of Maryland Baltimore County, Baltimore, MD, United States

[5]NASA Goddard Space Flight Center, Greenbelt, MD, United States

[6]Earth System Science Interdisciplinary Center, University of Maryland, College Park, MD, United States

[7]U.S. Naval Research Laboratory, Monterey, CA, United States

[*]*Correspondence*: Jun Wang (jun-wang-1@uiowa.edu)

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## Introduction

This supplement includes the descriptions of EPIC aerosol optical depth (AOD) and aerosol optical centroid height (AOCH) retrieval, calculation of dust mass extinction efficiency for MERRA-2 and Figure S1-S6. Figure S1 shows the number of the valid retrievals for monthly EPIC AOCH climatology from 4 years (June 2015 – June 2019) of EPIC measurements. Figure S2 displays the monthly mapping of total AOD, dust optical depth and smoke optical depth in our domain calculated from 13 years (June 2006 – June 2019) of CALIOP level 3 product. Figure S3 is the scatter plot for comparing the domain-averaged monthly AOCH climatology from EPIC versus CALIOP and from MERRA-2 versus CALIOP. Figure S4 presents the monthly mapping of the MERRA-2 AOCH climatology. Figures S5 and S6 show the 3-hourly mapping of Saharan dust layer height in wet season (May - October) over tropical North Atlantic Ocean (TNAO) from MERRA-2 dataset and 6-hourly mapping of the counterpart from NAAPS-RA dataset.

## Description of EPIC AOD and AOCH retrieval

The AOD is first determined using the two EPIC atmospheric window channels at 680 and 780 nm, and the AOCH is subsequently derived based on the ratios of two oxygen absorption bands to their neighboring continuum bands (764/780 and 688/680). Following Xu et al. (2017), the Saharan dust aerosol model was obtained from the climatology of AERONET data. We assumed that the aerosol vertical profile follows a quasi-Gaussian distribution (Spurr & Christi, 2014).

$$\tau(z) = C\frac{\exp(-h|z-H|)}{[1+\exp(-h|z-H|)]^2} \quad \text{(S1)}$$

where C is determined by total AOD, and h is related to the half-width parameter $\eta$ by $\eta = \frac{\ln(3+\sqrt{8})}{h}$. The half-width parameter is fixed at 1 km. The H retrieved from our algorithm represents the altitude where the maximum aerosol extinction coefficient is located, i.e., AOCH. The deviations of our retrieved AOCH from CALIOP counterparts are generally within 1 km. See Xu et al. (2017) for more details about the EPIC AOCH retrieval algorithm over ocean surface.

## Description of calculation of dust mass extinction efficiency for MERRA-2

The aerosol extinction coefficient at vertical layer i from MERRA-2 $\beta_{\mathrm{ext},i}$ for all 72 model layers is computed by Equation (S2).

$$\beta_{\mathrm{ext},i} = \sum_{j=1}^{m} k_{ij}\, r_{ij} \rho_i \qquad \text{(S2)}$$

here $k_{ij}$ is mass extinction efficiency of dust size bin j at vertical layer i; $r_{ij}$ is the mass mixing ratio of dust size bin j at vertical layer i from MERRA-2; and $\rho_i$ is the air density at vertical layer i from MERRA-2. The mass extinction efficiency for 5 dust size bins is taken from the lookup tables of aerosol optical properties used in GEOS-4/5 (Colarco et al., 2010; Colarco et al., 2014), which is then linearly interpolated from 675 and 870 nm to the same wavelength of EPIC AOCH retrieval at 680 nm.

## Description of Figures S1-S6

Figure S1 in this document maps the number of the valid retrievals (sample density) for monthly EPIC AOCH climatology over TNAO from 4 years (June 2015 – June 2019) of EPIC measurements. We calculated the monthly climatology of total AOD, dust optical depth and smoke optical depth over the domain of our interest using 13 years (June 2006 – June 2019) of CALIOP level 3 product. The results are shown in Figure S2. The scatter plot for comparing the domain-averaged monthly AOCH climatology from EPIC versus CALIOP and from MERRA-2 versus CALIOP is presented in Figure S3. To match the overpass time of CALIOP, only the EPIC data from 14:00 to 16:59 UTC and MERRA-2 data at 15:00 UTC are used in this comparison. The correlation coefficient (*R*), root mean square error (RMSE) and mean bias error (MBE) are calculated and labeled in Figure S3. Figure S4 is the monthly mapping of Saharan dust layer height over TNAO from 4 years (June 2015 – June 2019) of MERRA-2 data. Figure S5 and S6 present the diurnal mapping of the dust AOCH over the TNAO for the wet season (May - October) calculated from the multi-year (June 2015 – June 2019) average of MERRA-2 (Gelaro et al., 2017) and NAAPS-RA (Lynch et al., 2016)datasets, respectively. We only considered the model grid cells with AOD higher than 0.2 for the comparison with EPIC retrievals.

- Figure S1 shows the sample density map of monthly EPIC AOCH climatology.
- Figure S2 presents the monthly climatology of total AOD, dust optical depth and smoke optical depth from CALIOP level 3 product.
- Figure S3 is the scatter plot for comparing the domain-averaged monthly EPIC AOCH climatology and the counterparts from CALIOP data.
- Figure S4 presents the monthly mapping of dust AOCH from multi-year MERRA-2 data at 15:00 UTC.
- Figure S5 displays the 3-hourly mapping of dust AOCH in daytime from the 3-hourly instantaneous MERRA-2 dataset.
- Figure S6 presents the 6-hourly mapping of dust AOCH during the whole day from the NAAPS-RA reanalysis data.

**Figures S1-S6**

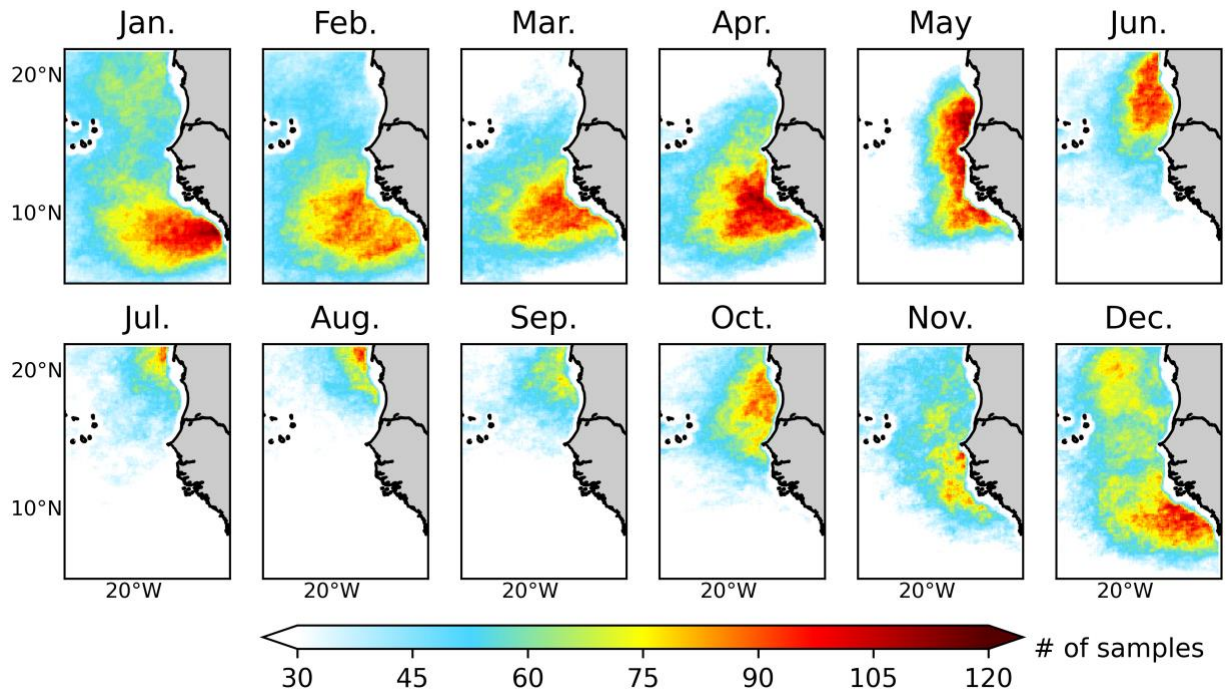


**Figure S1.** The number of valid retrievals for monthly EPIC AOCH climatology over TNAO from 4 years (June 2015 – June 2019) of EPIC measurements.

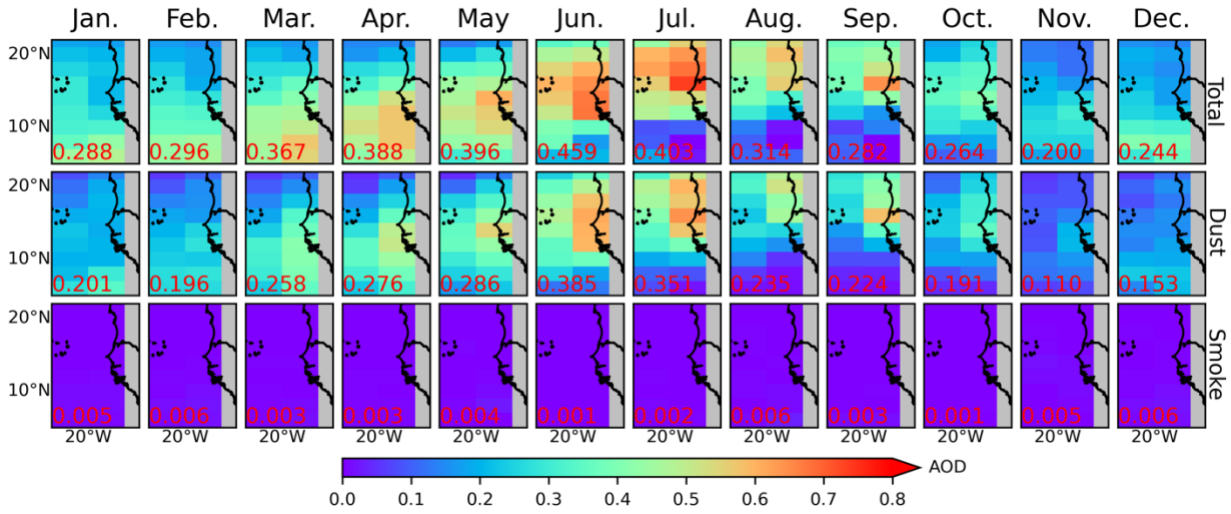


**Figure S2.** The monthly climatology of total AOD (top row), dust optical depth (middle row) and smoke optical depth (bottom row) over TNAO from 13 years (June 2006 – June 2019) of CALIOP level 3 product. The domain average is labeled by red font in each panel. The AOD values for dust and smoke are computed based on the CALIOP feature masks for different aerosol types. The AOD values for clean marine aerosols are not shown.

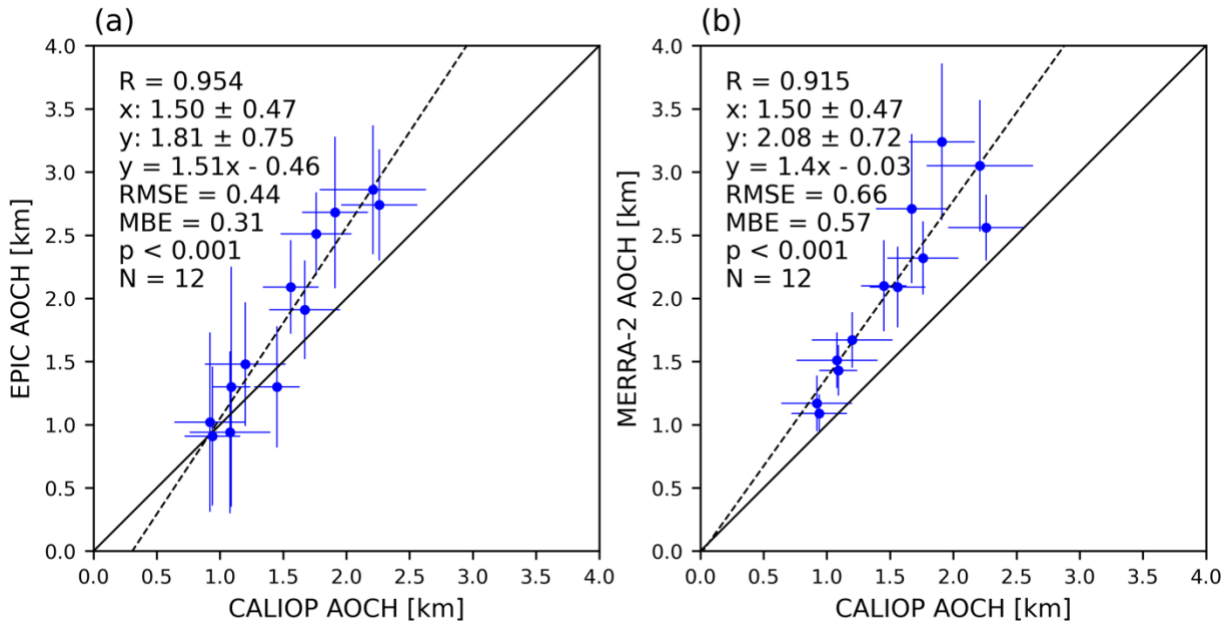


**Figure S3.** Scatter plot of monthly AOCH climatology from (a) EPIC versus CALIOP and (b) MERRA-2 versus CALIOP for 12 domain-averaged monthly data points. Only the EPIC data from 14:00 to 16:59 UTC and MERRA-2 data at 15:00 UTC were used to match the overpass time of CALIOP. The error bar represents the standard deviation of monthly AOCH climatology in the domain for each month. The correlation coefficient (*R*), mean and standard deviation of x and y axis, the fitted linear equation between x and y, root mean square error (RMSE) and mean bias error (MBE) are labeled in each panel.

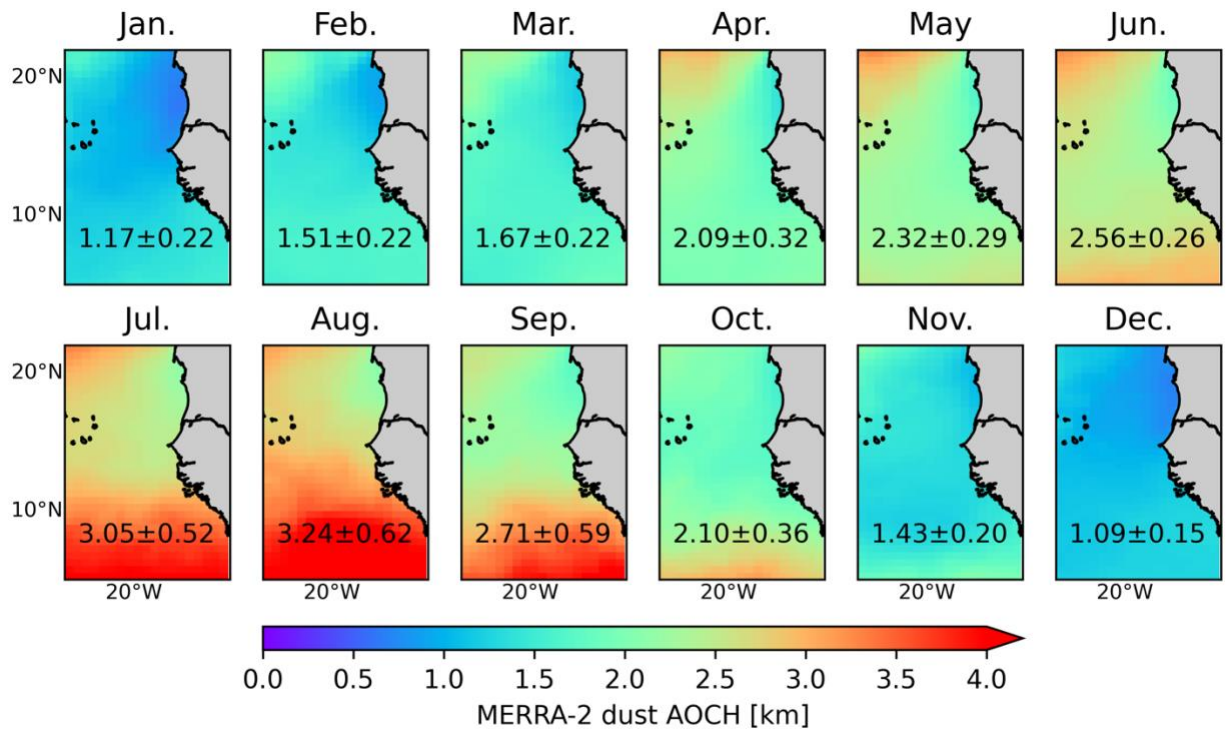


**Figure S4.** Monthly mapping of dust AOCH over TNAO from MERRA-2 (June 2015 – June 2019). Only the data at 15:00 UTC were used to match the overpass time of CALIOP. The domain average ± standard deviation for each month are labeled in each panel.

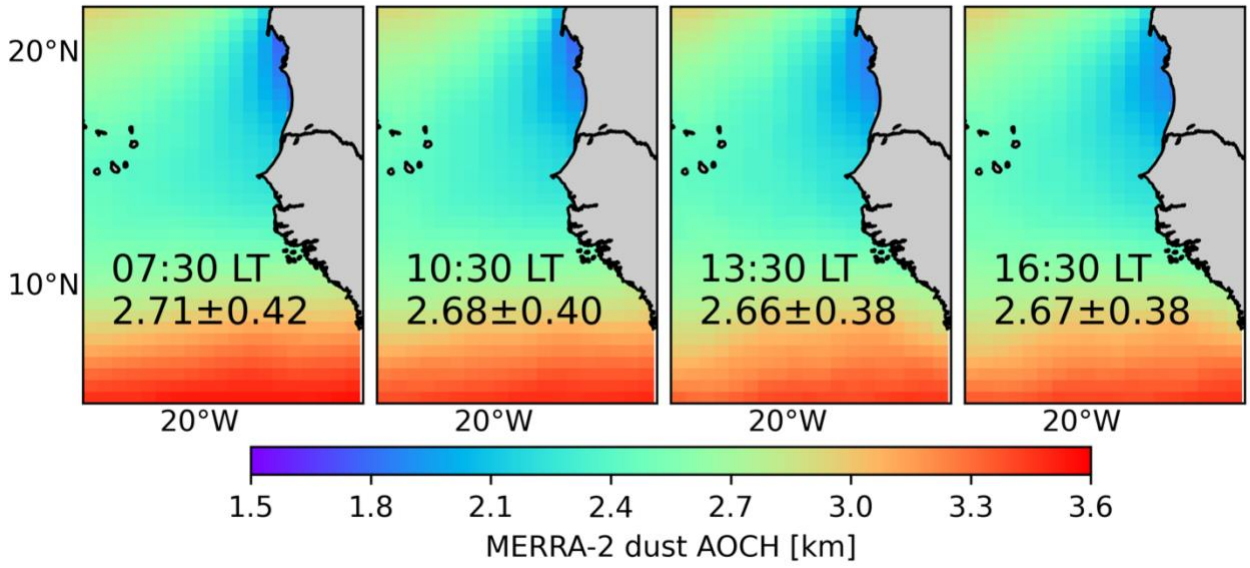


**Figure S5.** 3-hourly mapping of dust AOCH over TNAO in wet season from MERRA-2 (June 2015 – June 2019). The local time (LT) and domain average ± standard deviation are labeled in each panel.

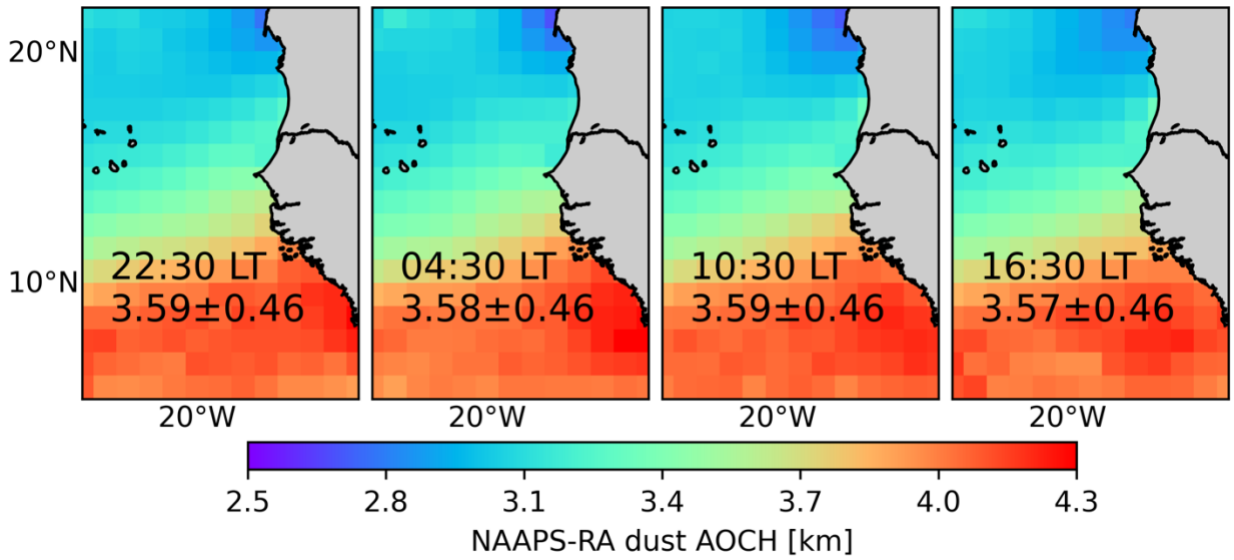


**Figure S6.** 6-hourly mapping of dust AOCH over TNAO in wet season from NAAPS-RA (June 2015 – June 2019). The local time (LT) and domain average ± standard deviation are labeled in each panel.

## References


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