

Figure S1: Global geographical distribution of dust lidar ratios considered in the upgraded CALIOP pure dust product.

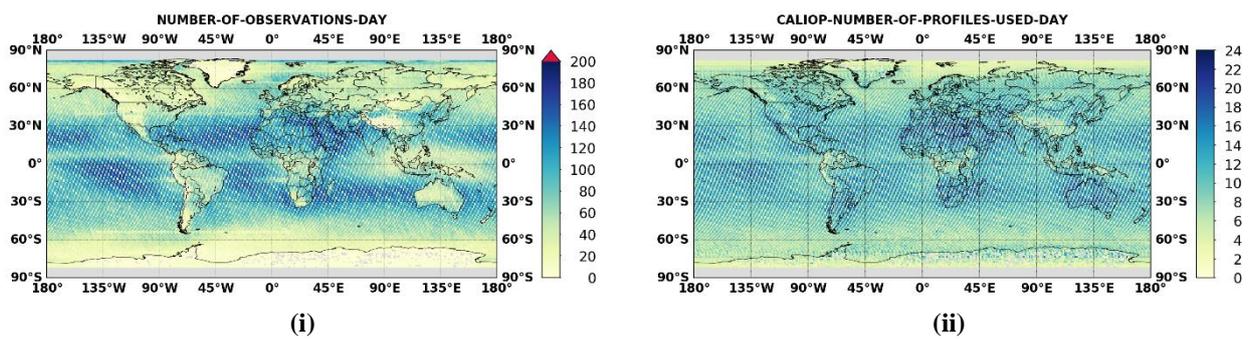


Figure S2: Global geographical distributions of the: **(i)** number of days with available CALIOP retrievals during the period 2007 – 2015 and **(ii)** average number of CALIOP profiles residing within the $1^\circ \times 1^\circ$ grid cell.

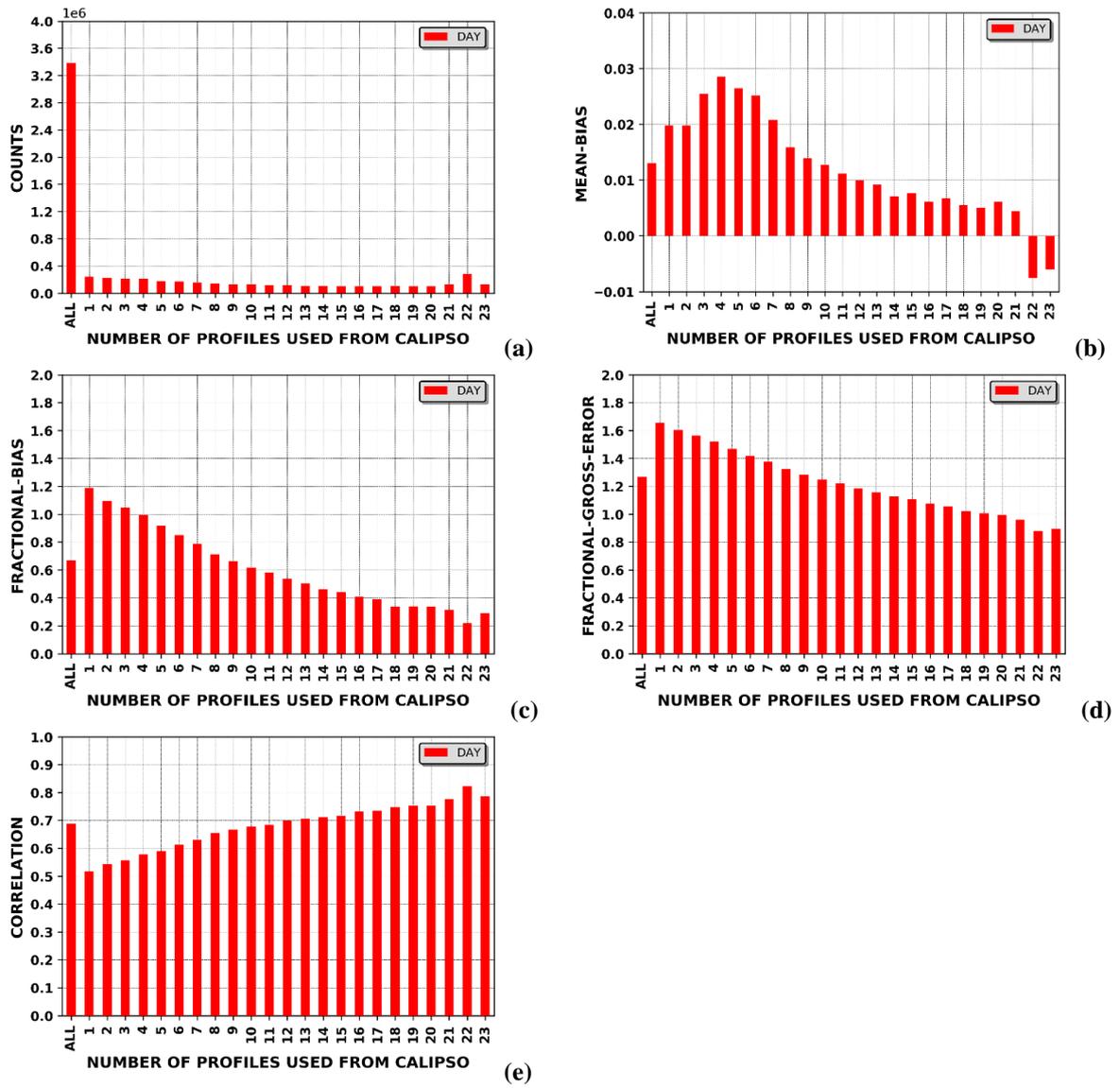


Figure S3: Histograms of: (a) number of CALIOP overpasses, (b) median bias, (c) fractional bias, (d) fractional gross error and (e) correlation coefficient calculated between MERRA-2 and CALIOP dust-to-total AODs, for daytime conditions over the period 2007 – 2015, at global scale, for bins of CALIOP profiles residing within the $1^\circ \times 1^\circ$ grid cell.

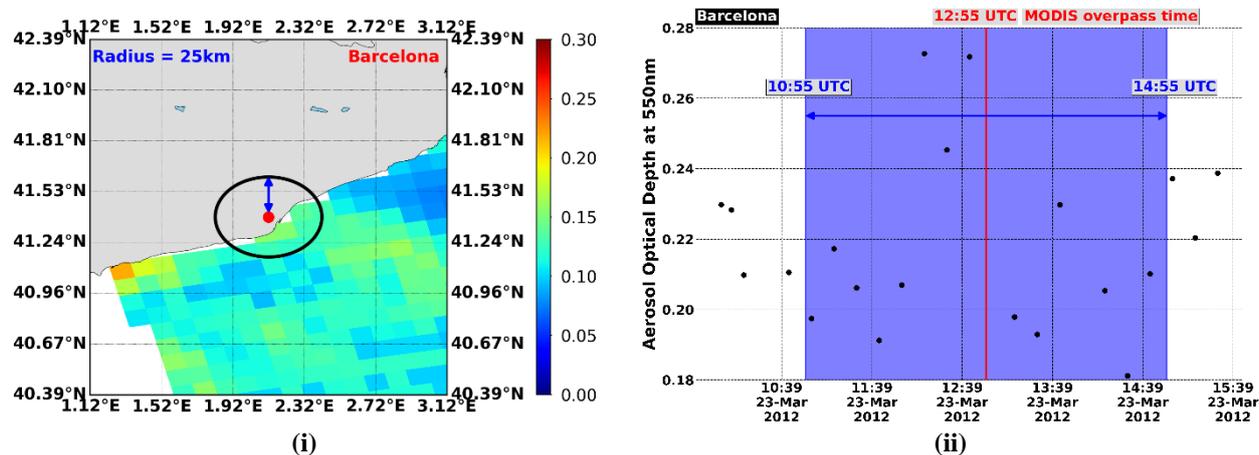


Figure S4: A schematic paradigm of the applied methodology for the collocation between MODIS L2 observations and AERONET almucantar retrievals. (i) The satellite AODs are spatially averaged, when at least one of them resides within the circle area (black curve), centered over an AERONET station (red dot), with a radius of 25 km (blue double-side arrow). (ii) The ground-based AODs (black circles) are temporally averaged when at least one of them falls within the time-window of 4 hours (blue shaded area) centered over the satellite overpass time (red thick line).

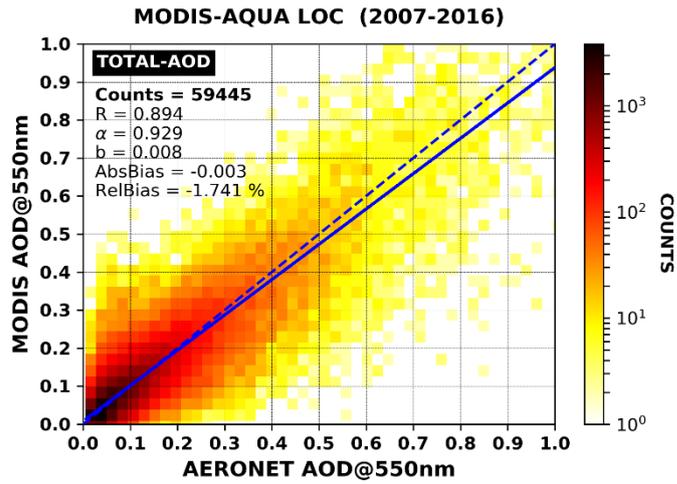
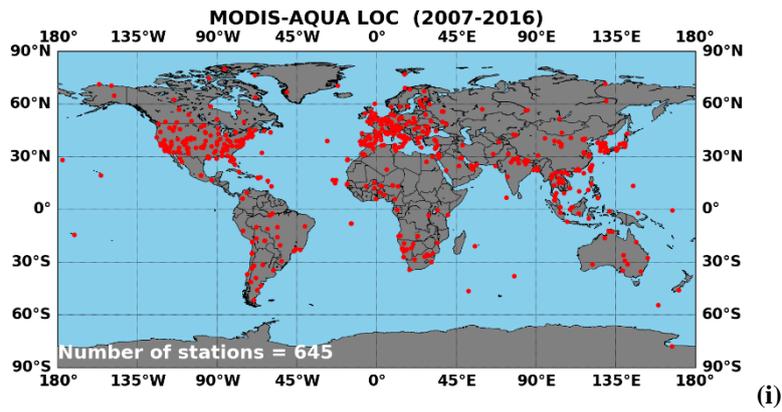


Figure S5: (i) AERONET sites where at least one pair of ground-based and spaceborne retrievals has been recorded, according to the defined collocation criteria, during the period 2007 – 2016. (ii) Density scatterplot between MODIS (y-axis) and AERONET (x-axis) aerosol optical depth at 550nm. The red solid and dashed lines stand for the linear regression fit and equal line ($y=x$), respectively. LOC in the titles indicates that both land (L) and ocean (OC) MODIS retrievals are considered.

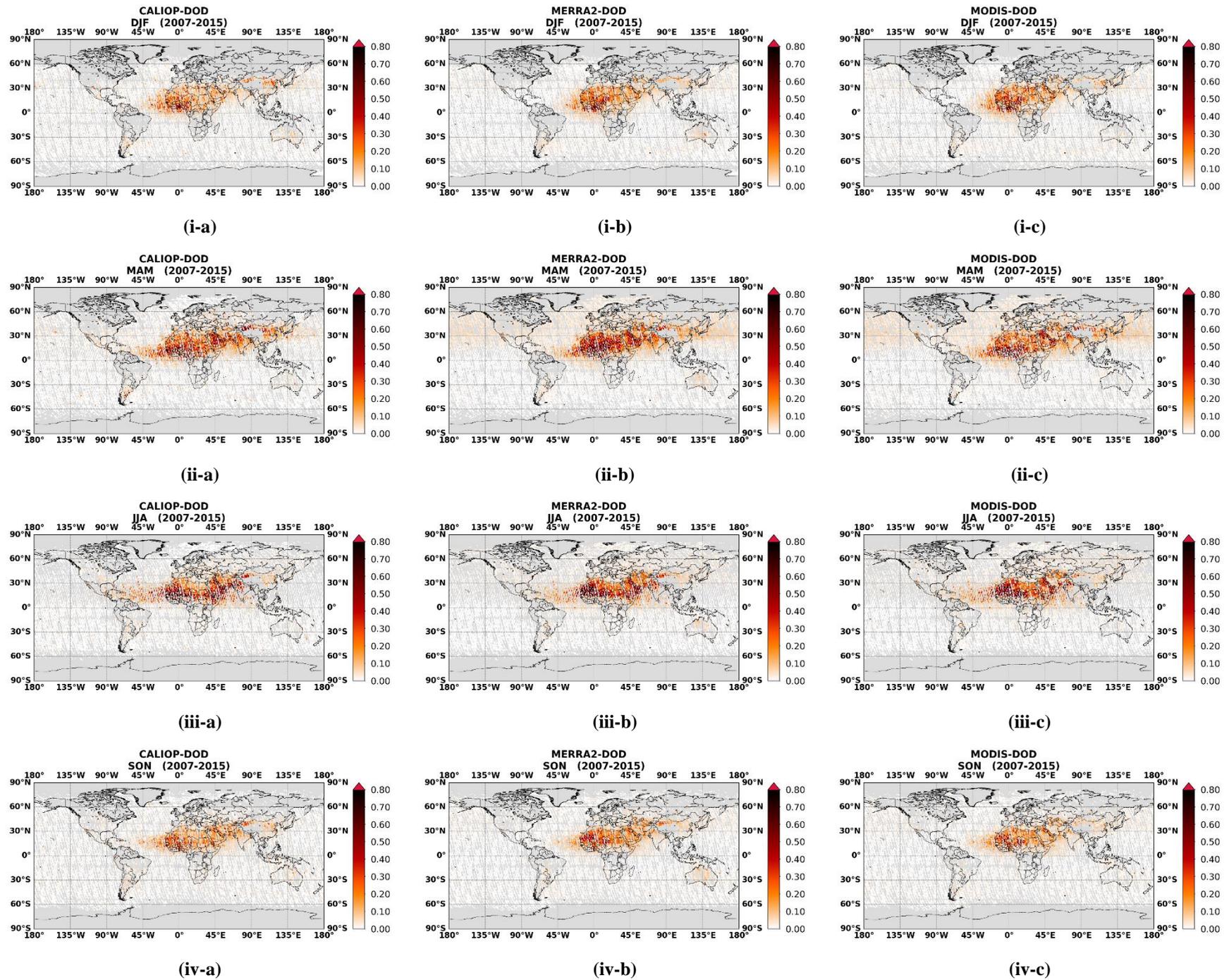


Figure S6: Seasonal geographical distributions, at $1^\circ \times 1^\circ$ spatial resolution, of daytime: (a) CALIOP DOD_{532nm}, (b) MERRA-2 DOD_{550nm} and (c) MIDAS (MODIS) DOD_{550nm}. The average maps, representative for the period 2007 – 2015, are presented separately for: (i) DJF, (ii) MAM, (iii) JJA and (iv) SON.

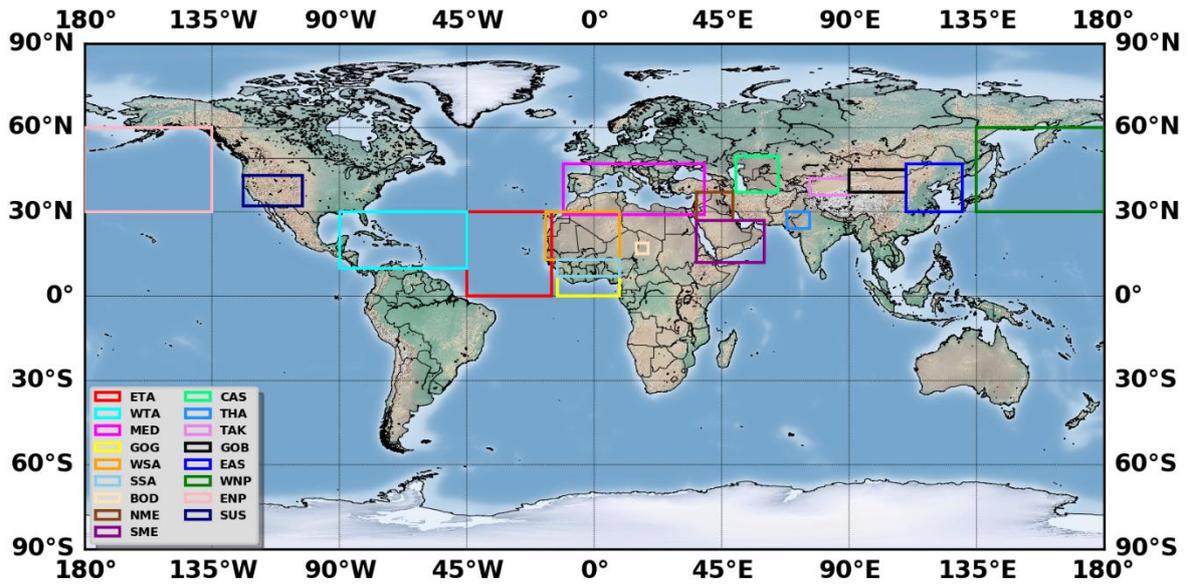
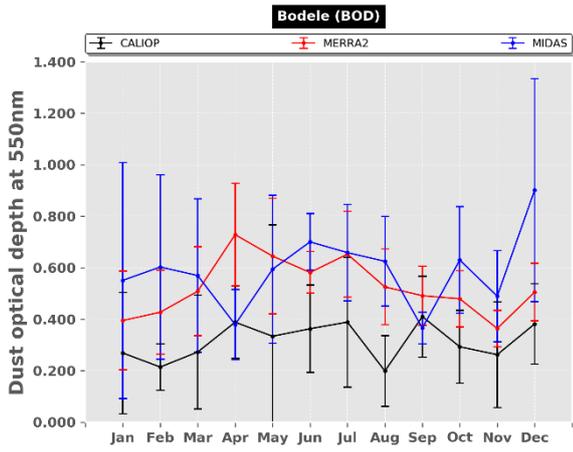
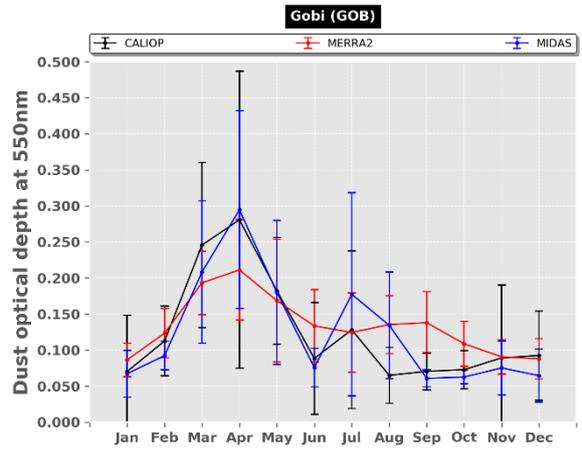


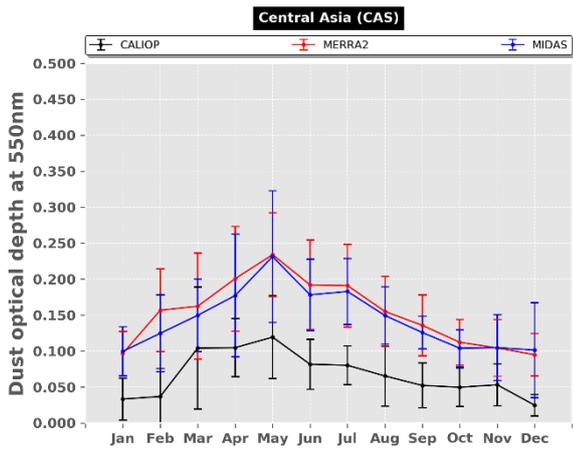
Figure S7: Regional domains of: *East Tropical Atlantic (ETA)*, *West Tropical Atlantic (WTA)*, *Mediterranean (MED)*, *Gulf of Guinea (GOG)*, *West Sahara (WSA)*, *Sub-Sahel (SSA)*, *Bodélé Depression (BOD)*, *North Middle East (NME)*, *South Middle East (SME)*, *Central Asia (CAS)*, *Thar Desert (THA)*, *Taklamakan Desert (TAK)*, *Gobi Desert (GOB)*, *East Asia (EAS)*, *West North Pacific (WNP)*, *East North Pacific (ENP)* and *Southwest United States (SUS)*.



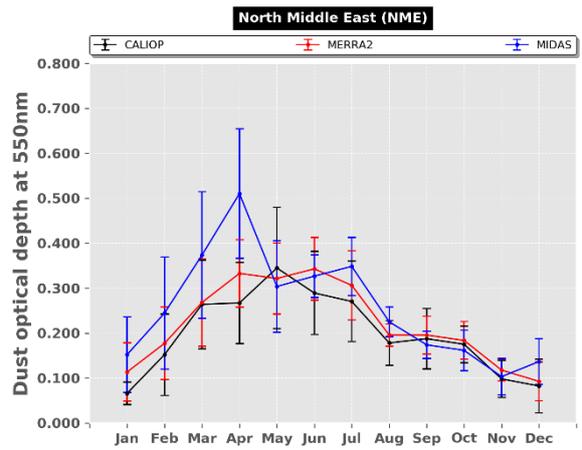
(a)



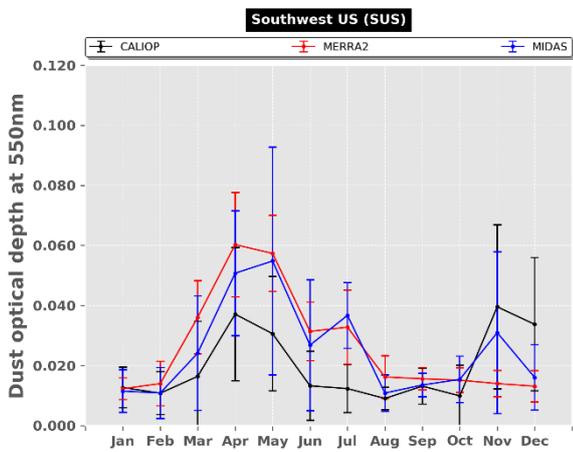
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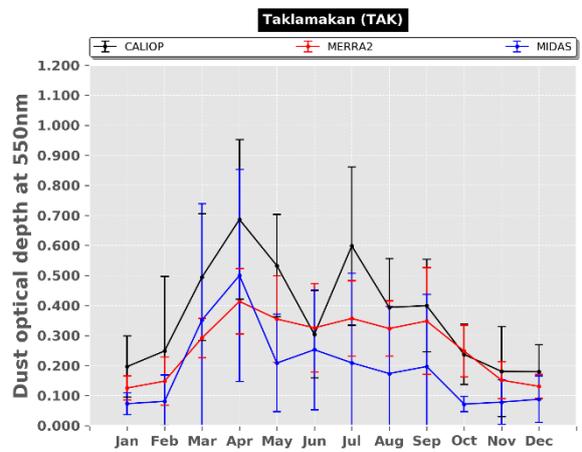
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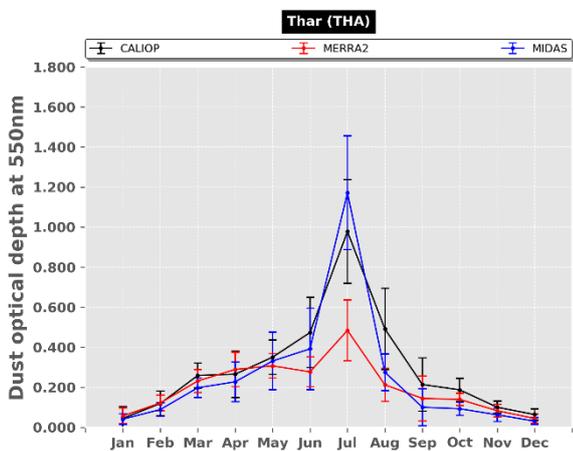
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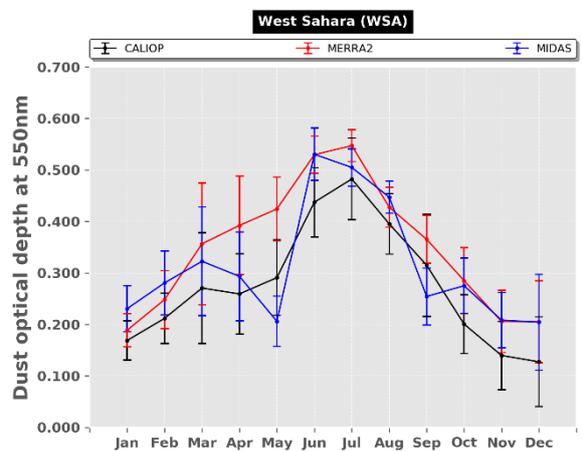
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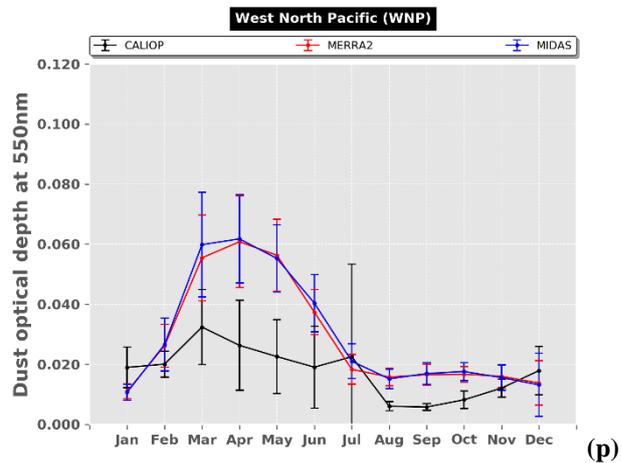
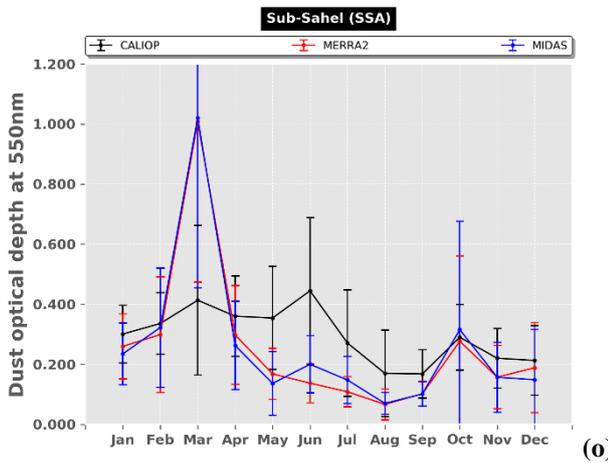
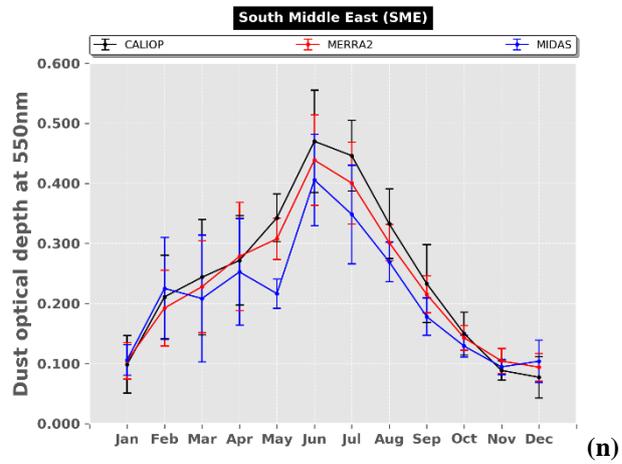
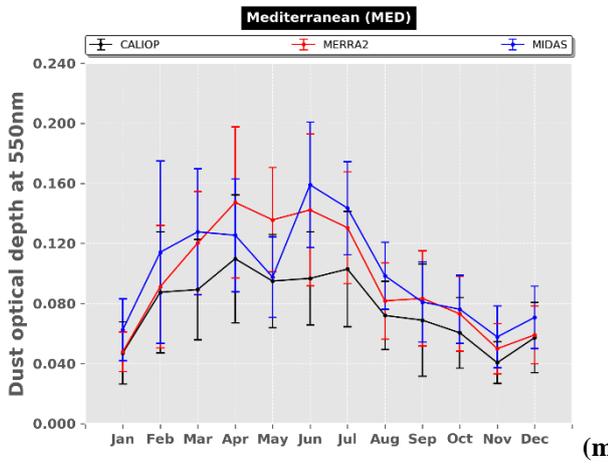
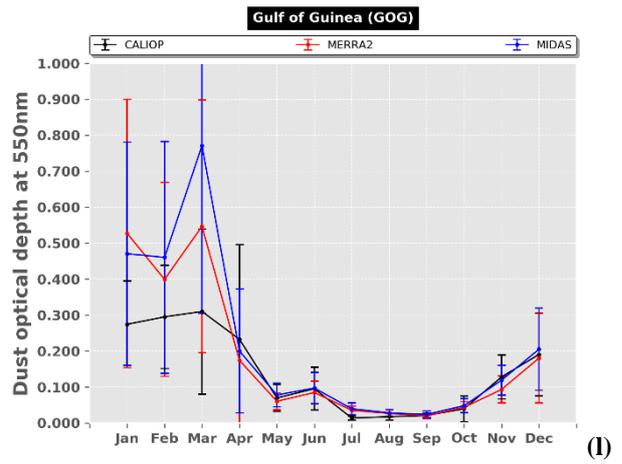
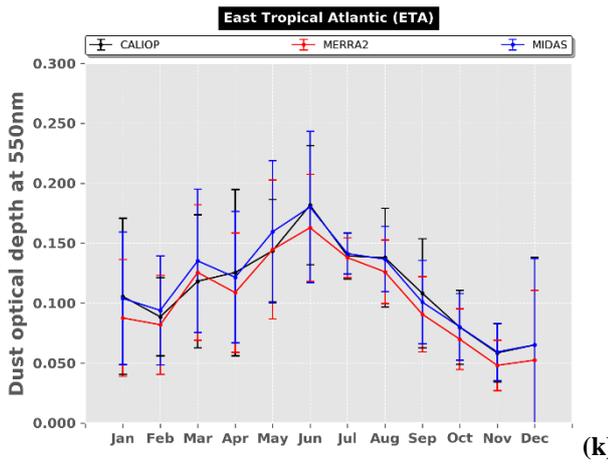
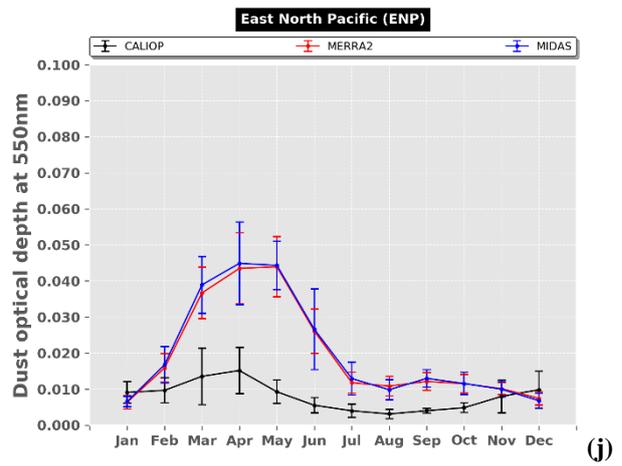
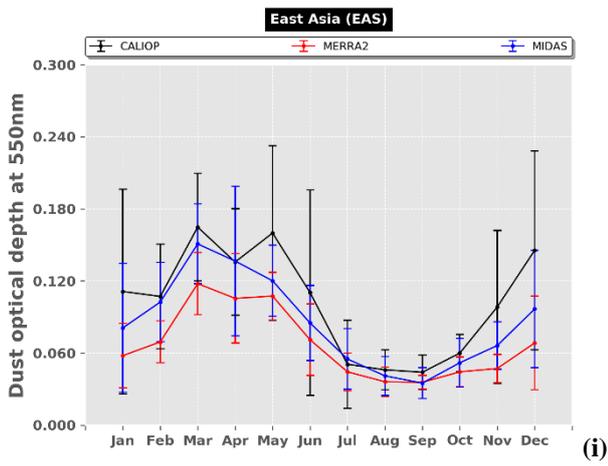
(f)



(g)



(h)



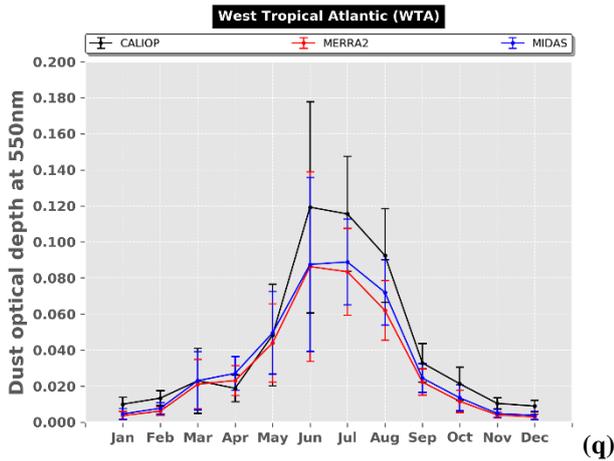
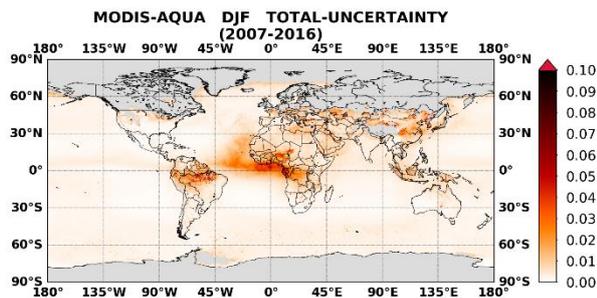
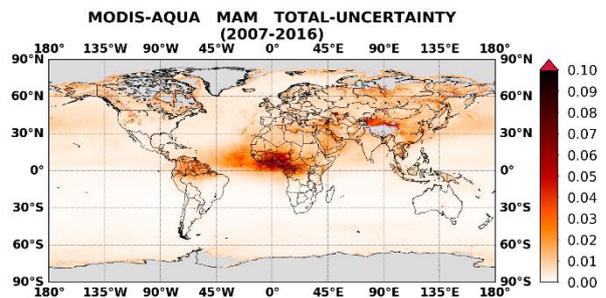


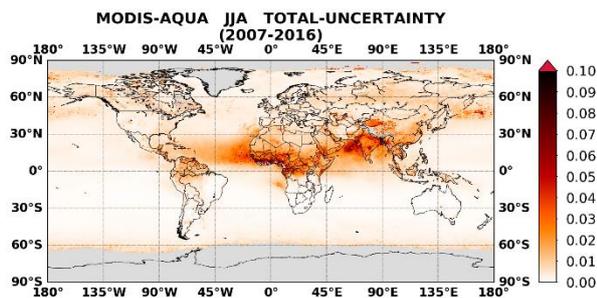
Figure S8: Intra-annual variability of CALIOP (black curve), MERRA-2 (red curve) and MODIS (blue curve) monthly DODs, regionally averaged over the: **(a)** Bodélé Depression (BOD), **(b)** Gobi Desert (GOB), **(c)** Kyzylkum Desert (KYZ), **(d)** North Middle East (NME), **(e)** southwest United States (SUS), **(f)** Taklamakan Desert (TAK), **(g)** Thar Desert (THA), **(h)** West Sahara (WSA), **(i)** East Asia (EAS), **(j)** East North Pacific (ENP), **(k)** East Tropical Atlantic (ETA), **(l)** Gulf of Guinea (GOG), **(m)** Mediterranean (MED), **(n)** South Middle East (SME), **(o)** Sub-Sahel (SSA), **(p)** West North Pacific (WNP) and **(q)** West Tropical Atlantic (WTA). The error bars correspond to the standard deviation computed from the interannual timeseries during the period 2007 – 2015.



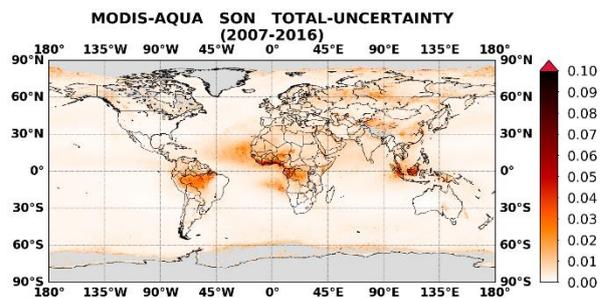
(i)



(ii)



(iii)



(iv)

Figure S9: Seasonal geographical distributions of the total DOD uncertainty for: **(i)** December-January-February (DJF), **(ii)** March-April-May (MAM), **(iii)** June-July-August (JJA) and **(iv)** September-October-November (SON) over the period 2007 – 2016.