Global dust climatology based on MODIS C6.1 and OMI-OMAERUV satellite data for the period 2005 - 2019

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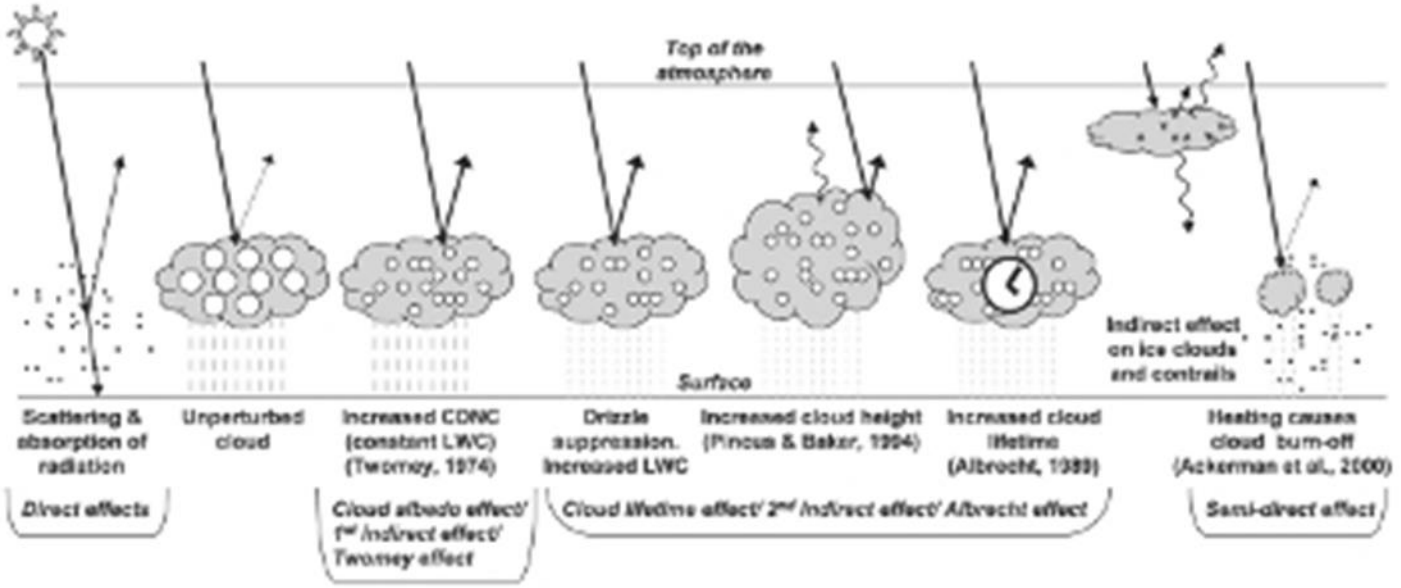
Aerosols

- Aerosols are broadly studied during the last decades, because of their multifaceted effects

- Aerosols effects on **weather** and **climate** patterns:

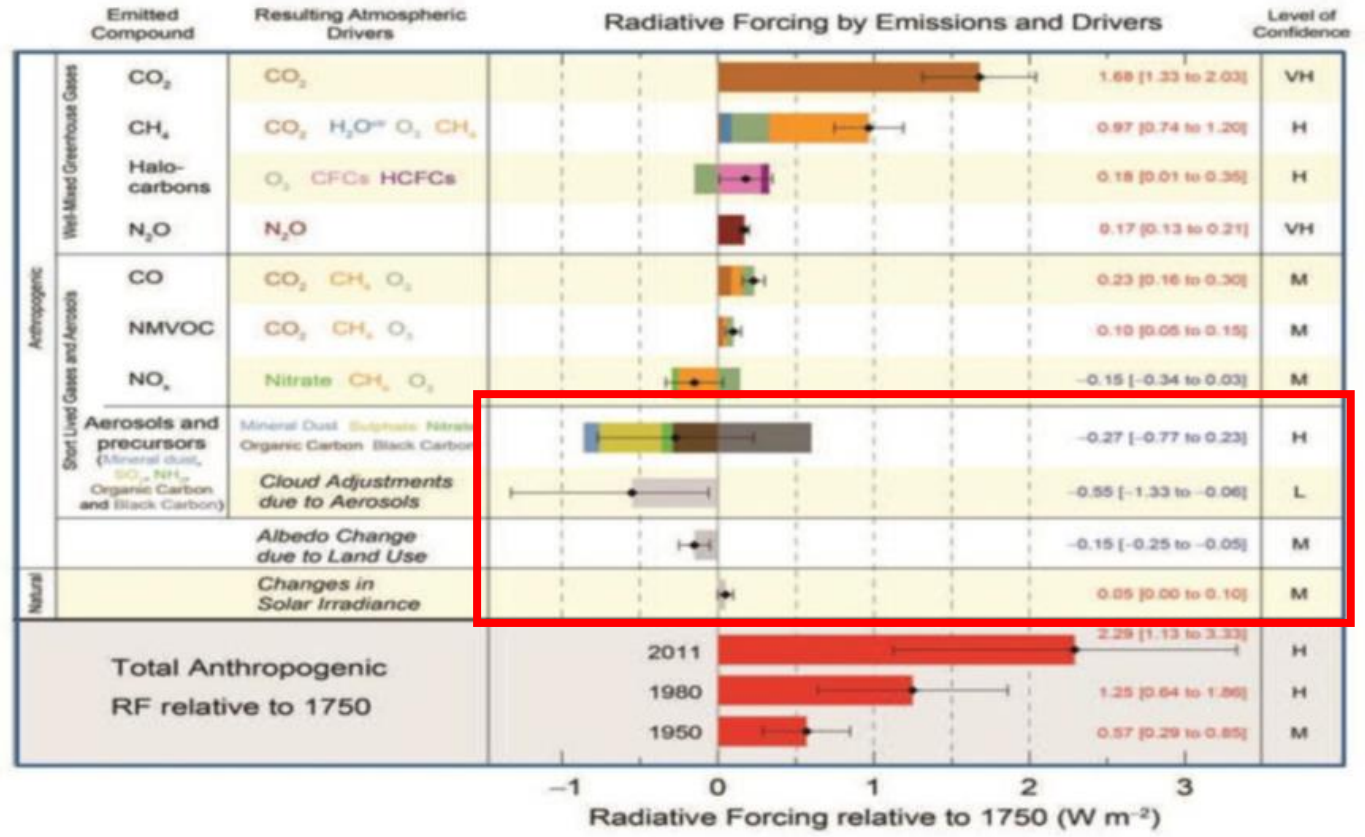
    1. Direct effect (absorption and scattering, more of SW and less of LW radiation)
    2. Indirect effect (aerosol-cloud interactions)
    3. Semi-direct effect



IPCC (2007)

Aerosols

Although aerosols are extensively investigated during the last decades, they still contribute the highest degree of uncertainty in climate projections (IPCC, 2013)



Dust Aerosols

- **Dust aerosols are one of the most interesting aerosol types, because:**

  1. They contribute a major part of the total aerosol **load** in the atmosphere
  2. They have variable **shape, physical and chemical properties**
  3. They **are transported** far away from their sources
  4. They are **absorbing radiation** (*direct and semi-direct effect*)
  5. They can act as **Cloud Condensation Nuclei (CCN)** as well as **Ice Nuclei (IC)** (*indirect effect*)

- **Dust aerosols properties:**

  1. Coarse aerosols ($2\mu m \leq d \leq 10\mu m$)
  2. Absorbing aerosols

these two properties enable their identification e.g. through the used satellite-based algorithm here!

Input Data

MODIS (Moderate Resolution Imaging Spectroradiometer)	OMI (Ozone Monitoring Instrument)
Satellite: Aqua **Collection:** Collection 6.1 **Processing Level:** Level-3 **Temporal Resolution:** Daily **Spatial Resolution:** 1°x1° **Spatial Coverage:** Global	**Satellite:** Aura **Collection:** OMAERUV **Processing Level:** Level-3 **Temporal Resolution:** Daily **Spatial Resolution:** 1°x1° **Spatial Coverage:** Global
Used Data: **Spectral Aerosol Optical Depth (AOD),** 7 wavelengths, above ocean and 3 above land	Used Data: **Aerosol Index (AI)**

The algorithm

Algorithm philosophy:

The algorithm takes advantage of the dust aerosols' optical properties in order to distinguish between them and other aerosol types into the atmospheric column. More specifically, the algorithm applies specific thresholds on: (i) Aerosol Index (AI) and (ii) Angstrom Exponent (a), and determines the presence or the absence of DD aerosols.

$$AI = 100log_{10}\left(\frac{I_{360}^{Meas}}{I_{360}^{calc}}\right)$$

where, I_{360}^{Meas} is the measured, and I_{360}^{calc} the theoretically calculated for an aerosol free atmosphere, backscattered radiation at 360nm

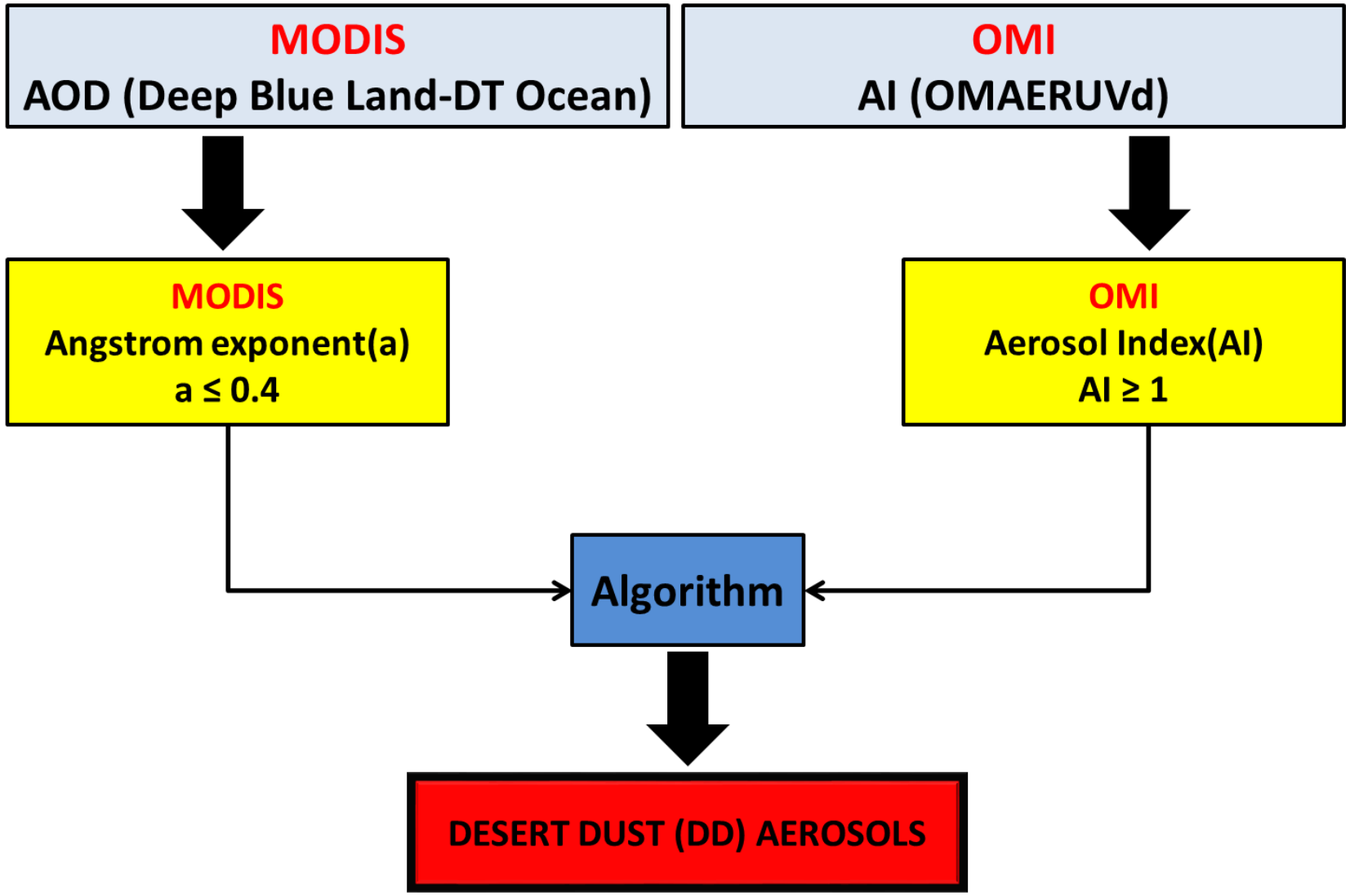
Absorption parameter

$$a = -\frac{dlogk_{ext}}{dlog\lambda} \approx -\frac{log\frac{AOD_{\lambda 1}}{AOD\lambda 2}}{log\frac{\lambda_1}{\lambda_2}}$$

where, k_{ext1} and k_{ext2} is the total extinction at $\lambda 1$ and $\lambda 2$ wavelengths respectively

Size parameter

The algorithm



Methodology

- Satellite data covering the 15-year period ***2005-2019***
- The satellite algorithm ran separately for each year
- The satellite algorithm operated on a ***daily*** and on a ***1°x1°* grid *basis***
- For each day and pixel, the algorithm determined the presence or absence of dust aerosols
- Next, spatio-temporal averaging procedures were applied
- For every year the algorithm calculated:

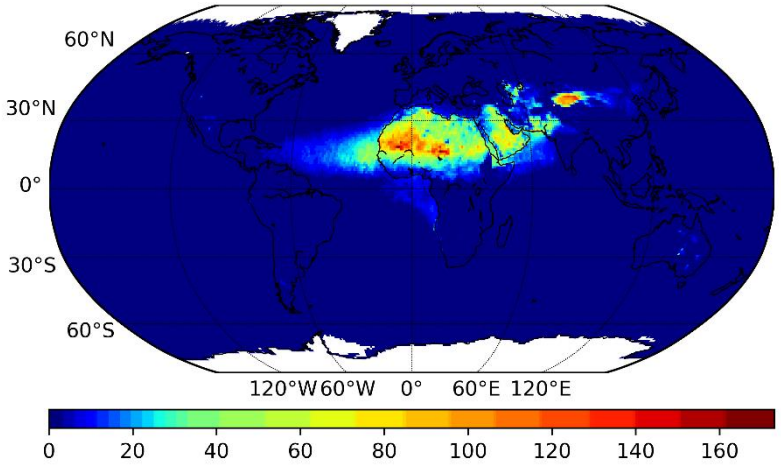
  a. The annual mean values of: (i) the ***Dust Optical Depth (DOD) at 550nm*** and (ii) the dust ***absolute and relative frequency*** of occurrence, on a pixel level basis
  b. The monthly mean values of: (i) DOD and (ii) dust absolute and relative frequency of occurrence, on a pixel level basis
  c. The spatially averaged values of: (i) the DOD and (ii) the Dust Frequencies of occurrence, for the entire globe as well as for selected regions with special interest related to dust

- Finally, using the results of all years of the study period, a ***climatological investigation*** (including computation of climatological mean values and examination of seasonal cycles and inter-annual variations and trends) is conducted

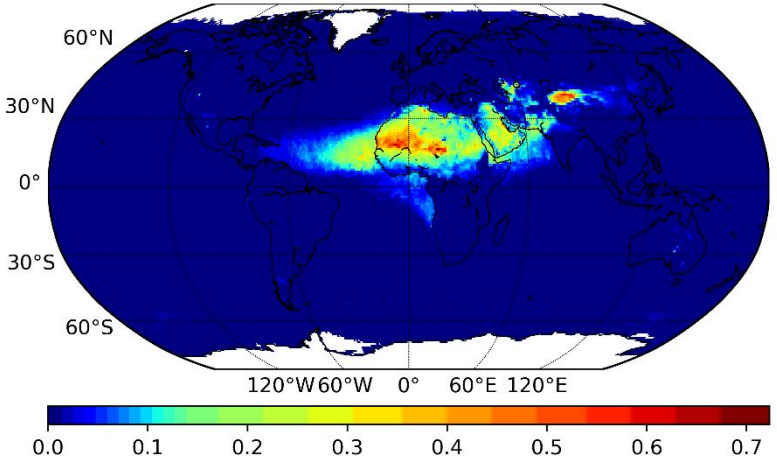
Results

Climatological (2005-2019) mean annual distributions

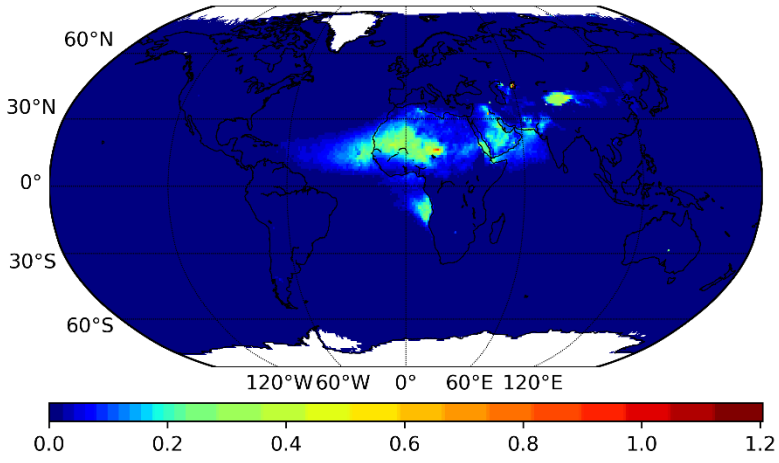
Absolute frequency of occurrence (days/year)



Relative frequency of occurrence



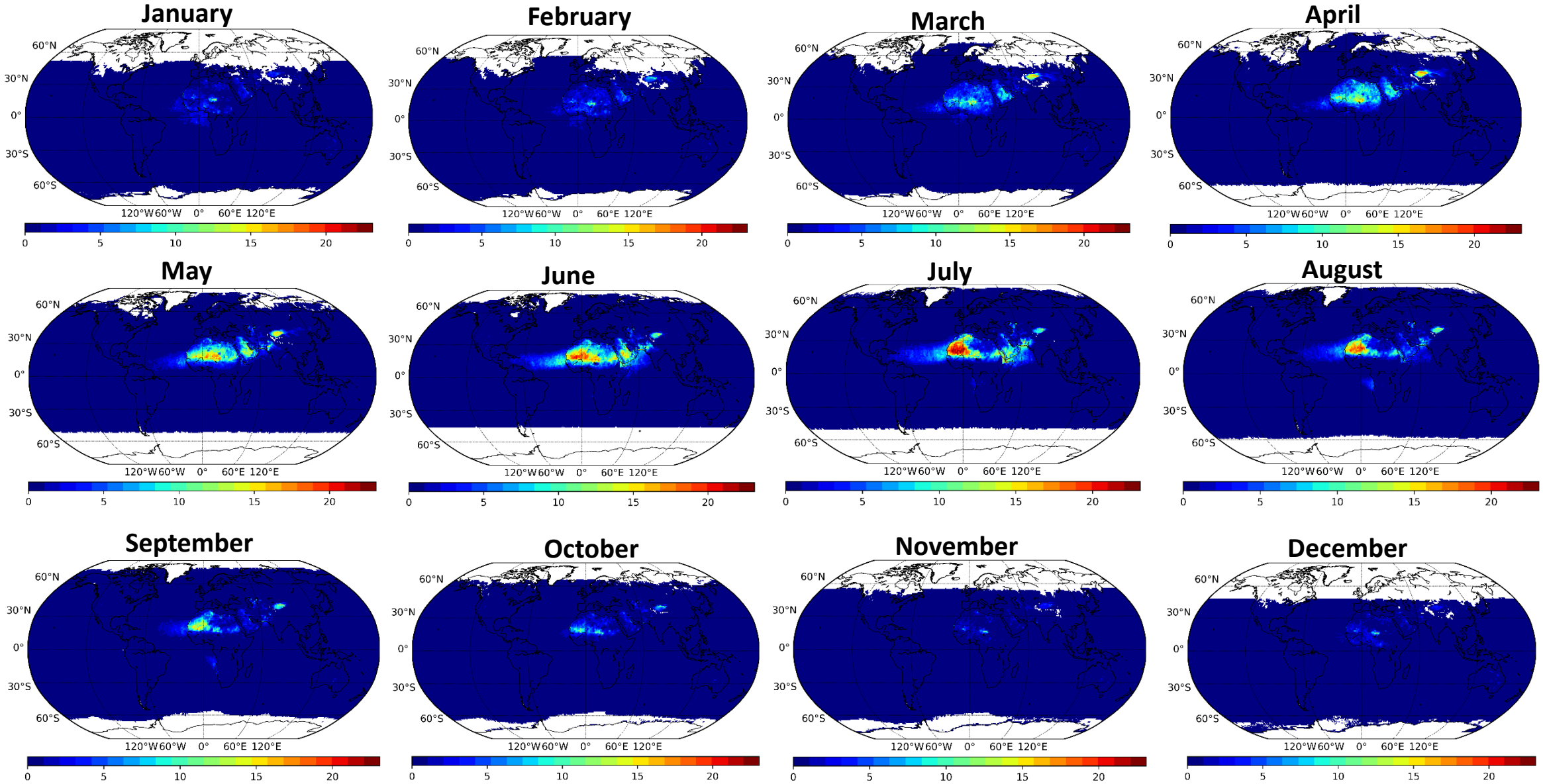
Dust Optical Depth



- More dust amounts in the North Hemisphere
- The three distributions have similar characteristics

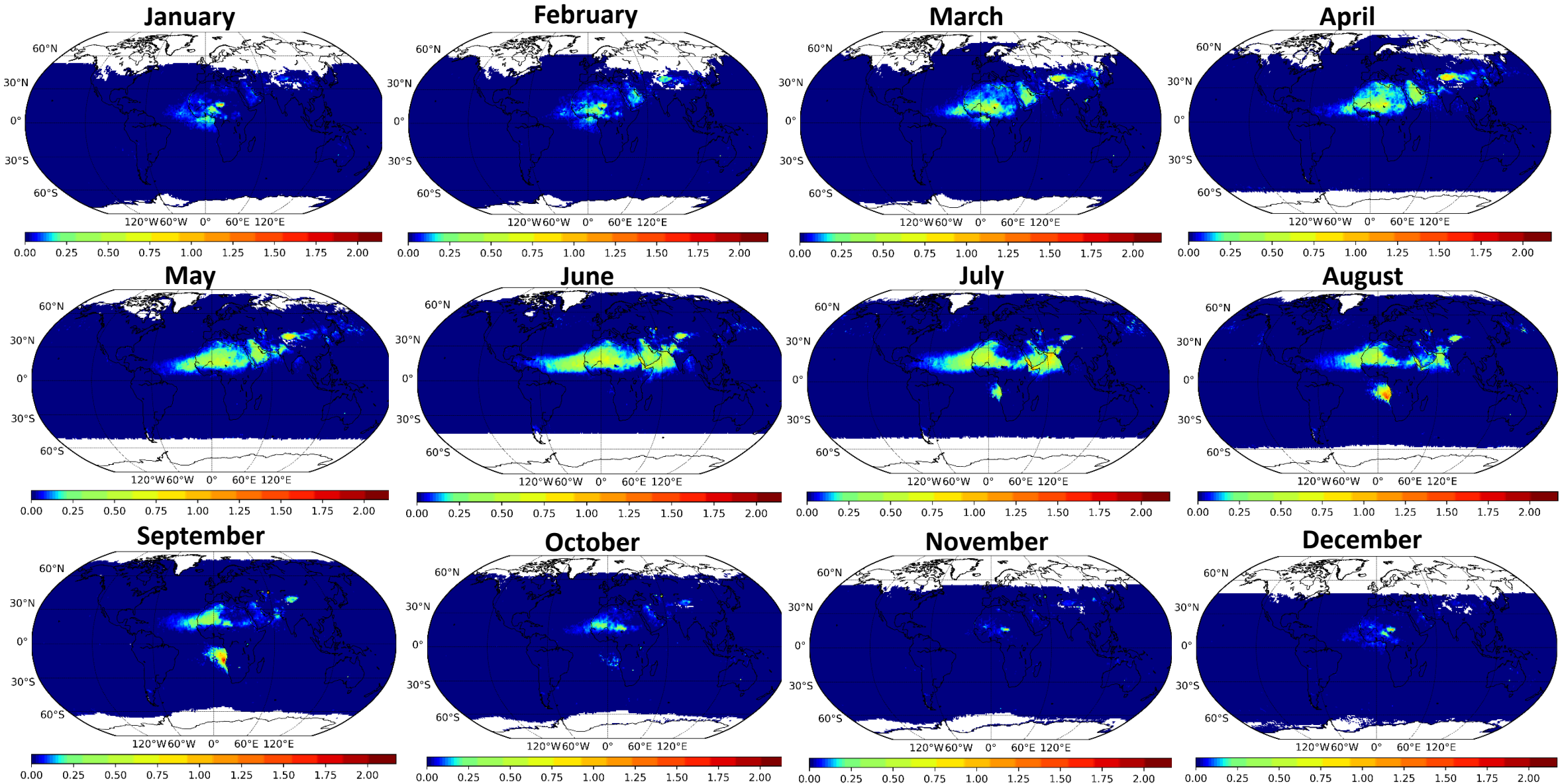
Results

Climatological (2005-2019) mean monthly distributions | Absolute frequency of occurrence



Results

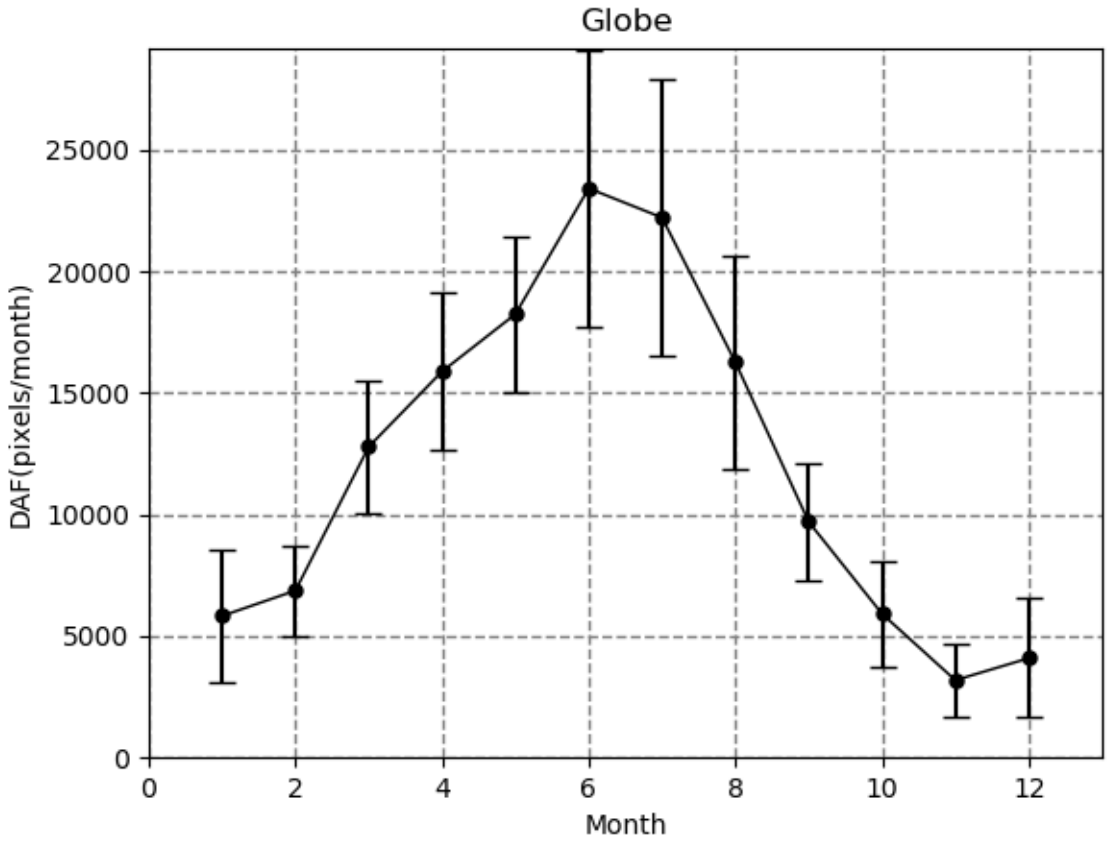
Climatological (2005-2019) mean monthly distributions | Dust Optical Depth

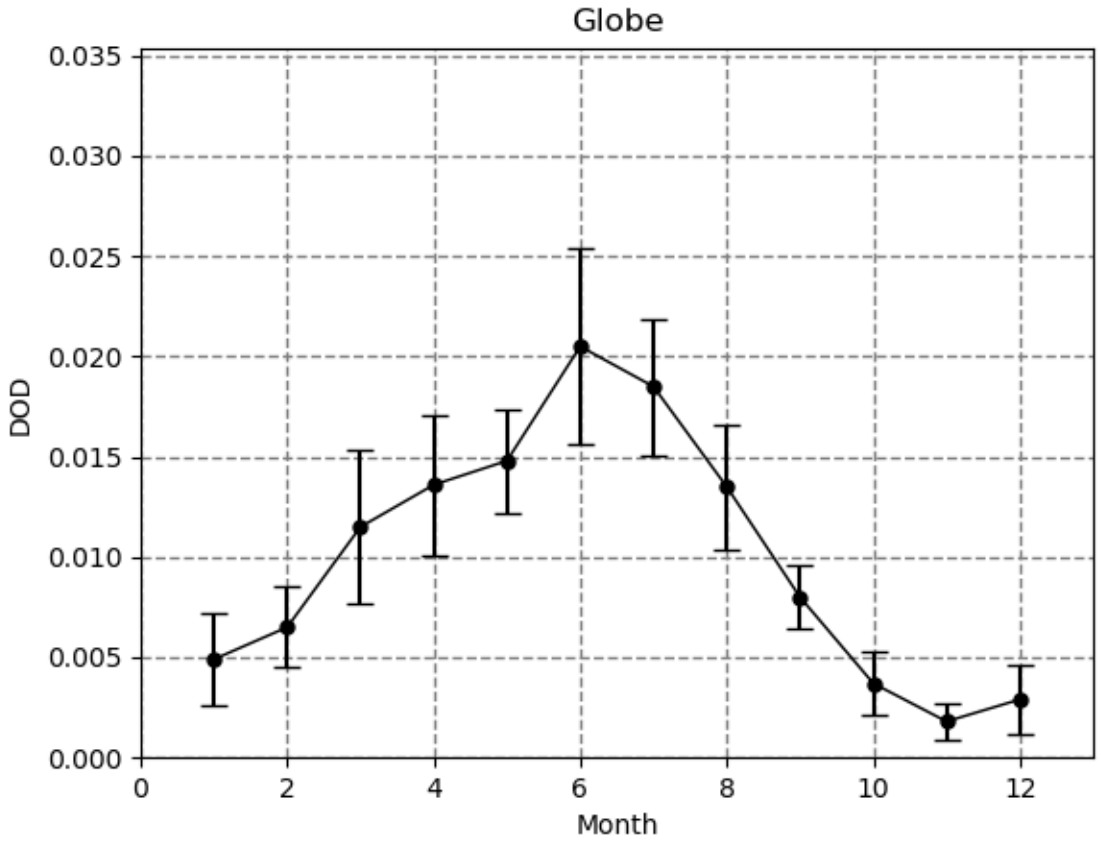


Results

Intra-annual variability of the total number of pixels where dust aerosols occurred (Dust Aerosol Frequency, DAF) and DOD| Global

On a global basis maximum values of both DAF and DOD are noted in boreal summer!
This is explained from the greater contribution of N. Hemisphere on the global dust loads…

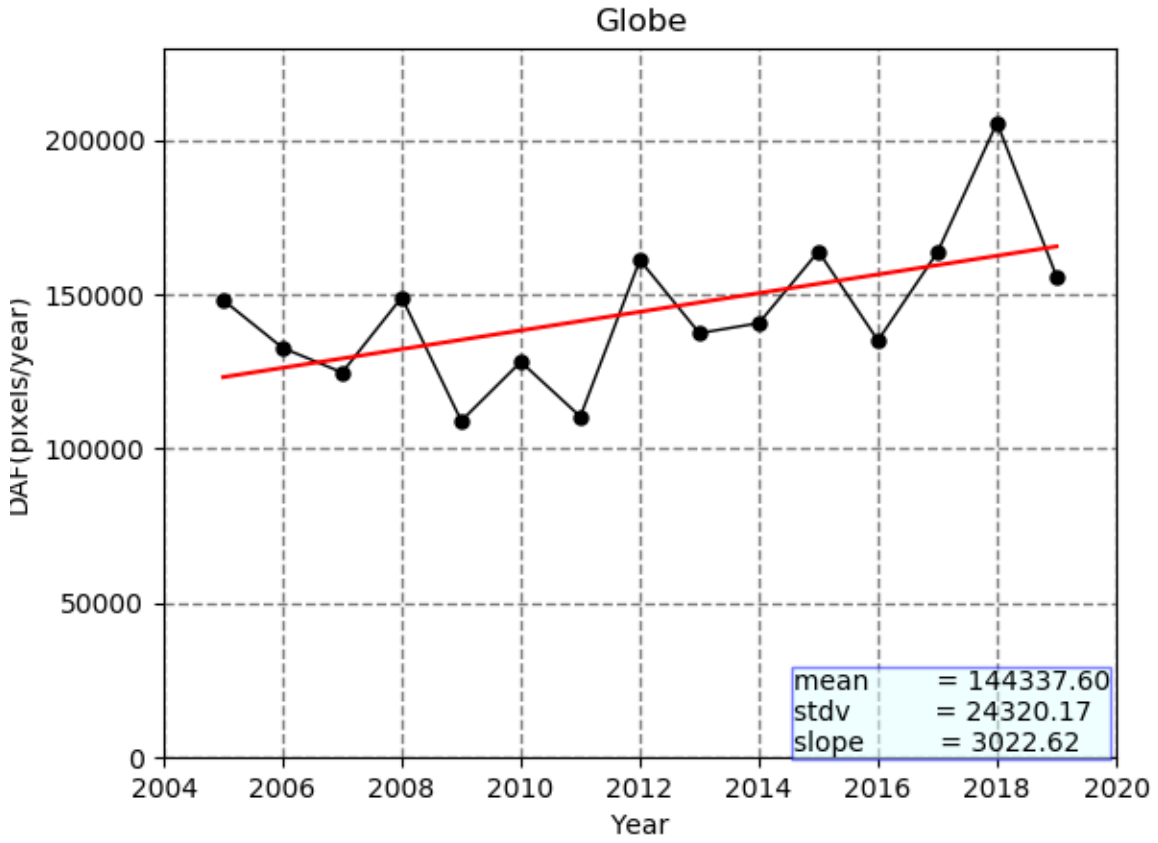


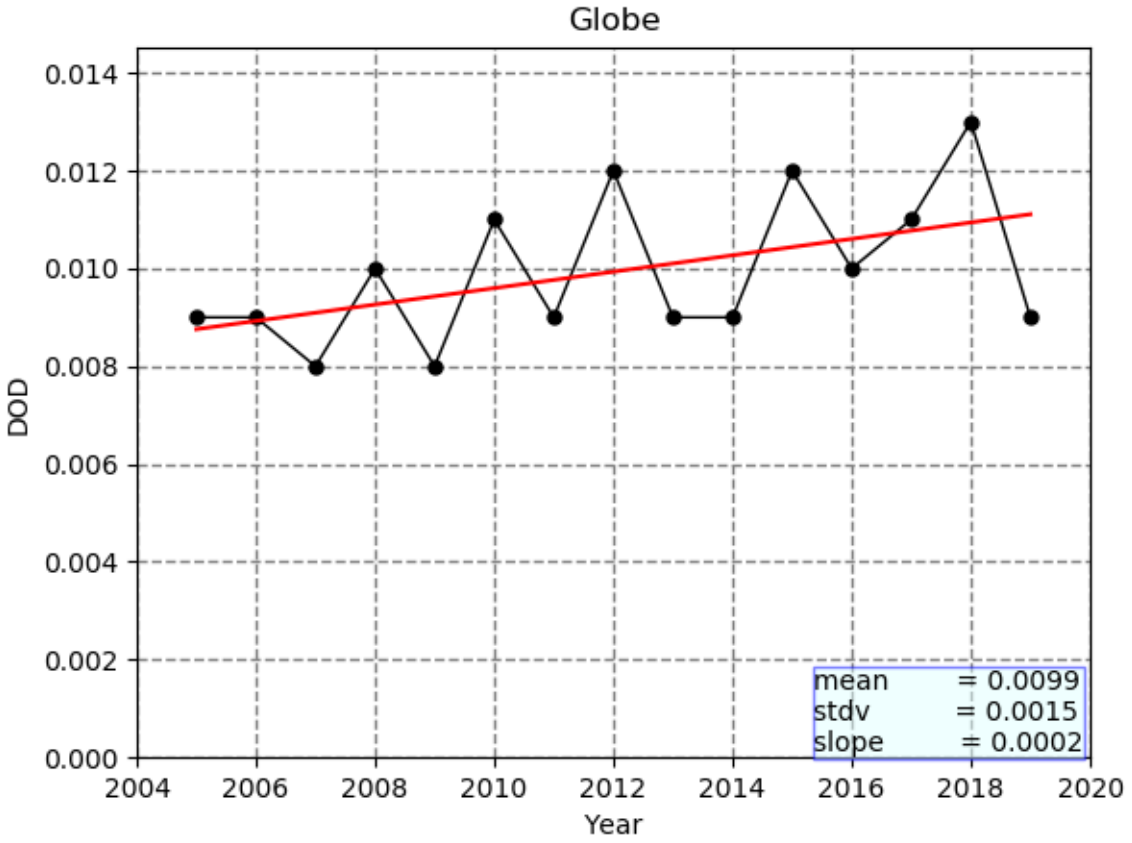


Note that errorbars corresponds to the uncertainty inserted from the year to year averaging!

Results

Interannual variability of the total number of pixels where dust aerosols occurred (Dust Aerosol Frequency, DAF) and DOD| Global

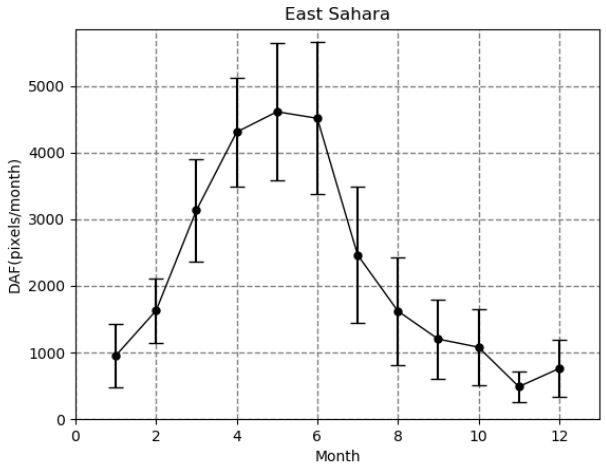


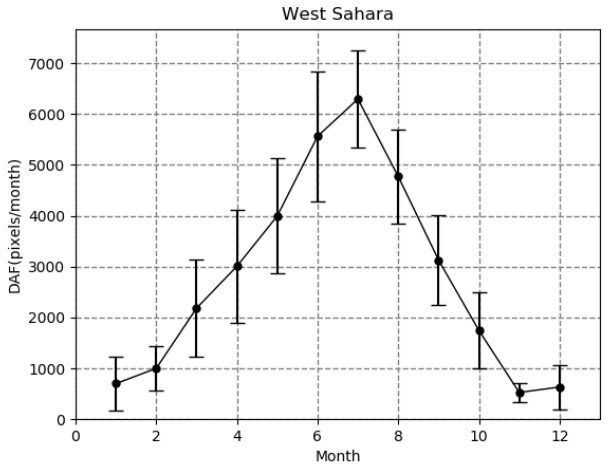


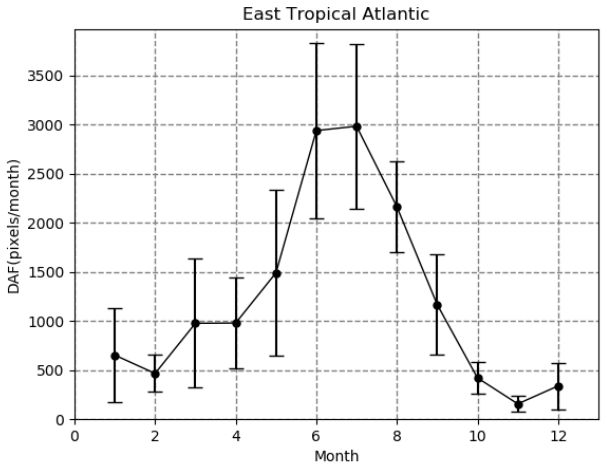
DAF and DOD have been increased during the last 15 years…

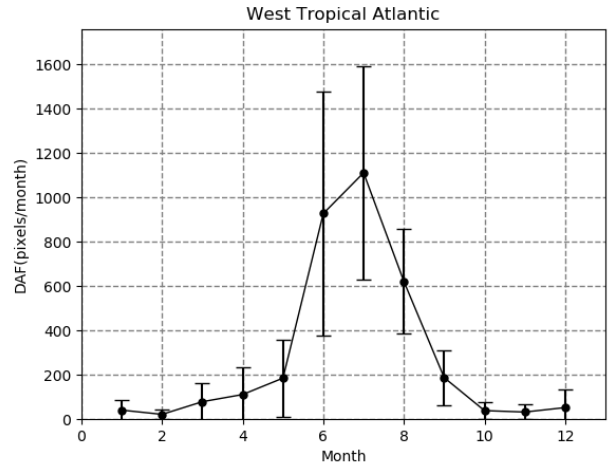
Results

Intra-annual variability of the total number of pixels where dust aerosols occurred (Dust Aerosol Frequency, DAF) | Regional

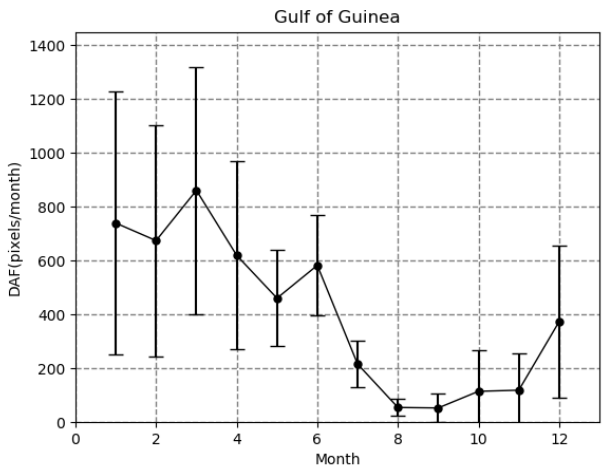


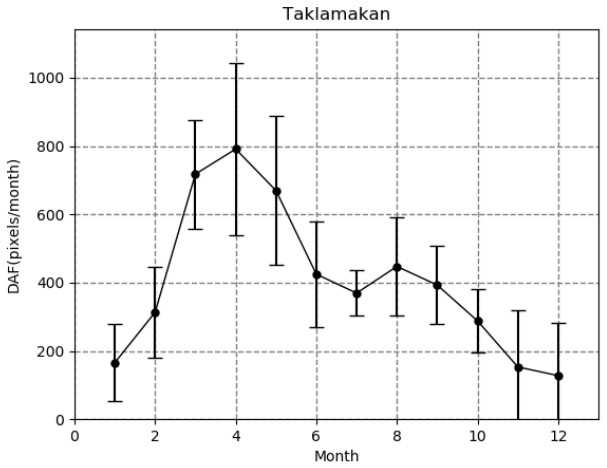


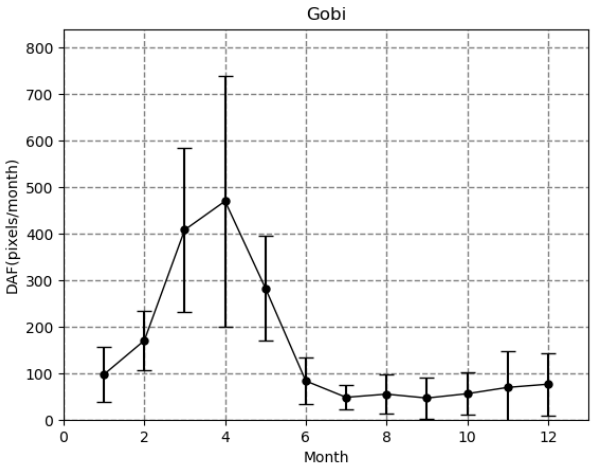




In most of the study regions the annual peak of DAF is noted on boreal summer and/or spring

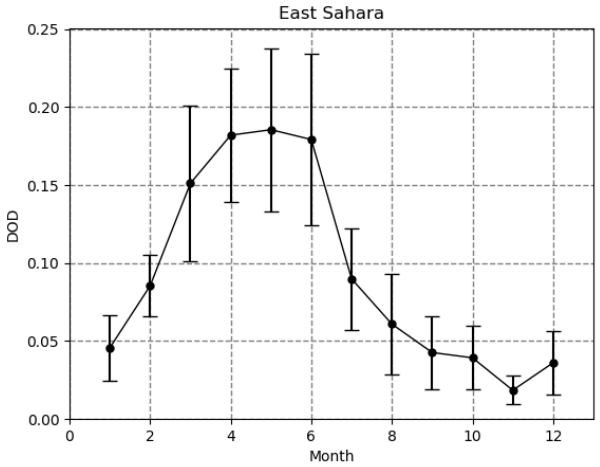


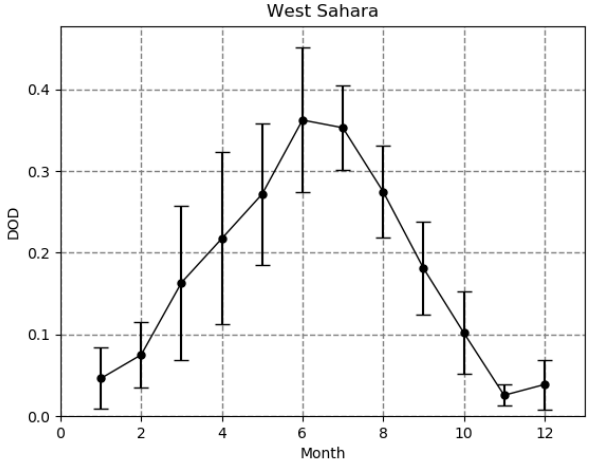


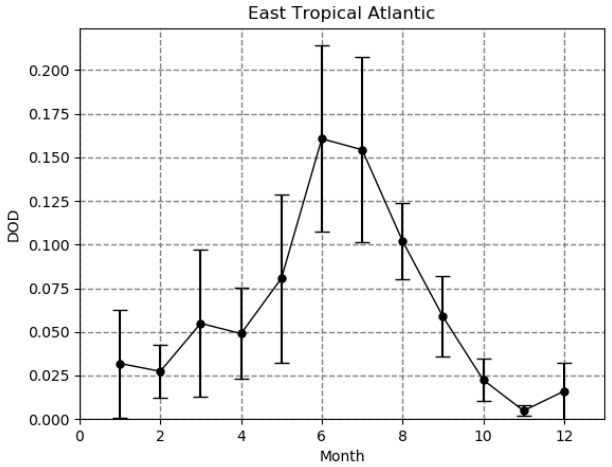


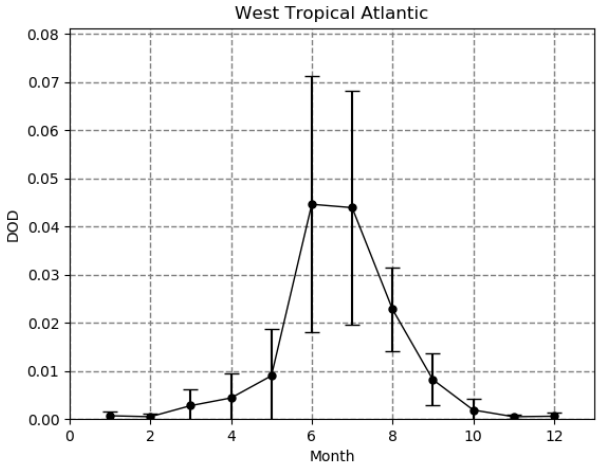
Results

Intra-annual variability of DOD| Regional

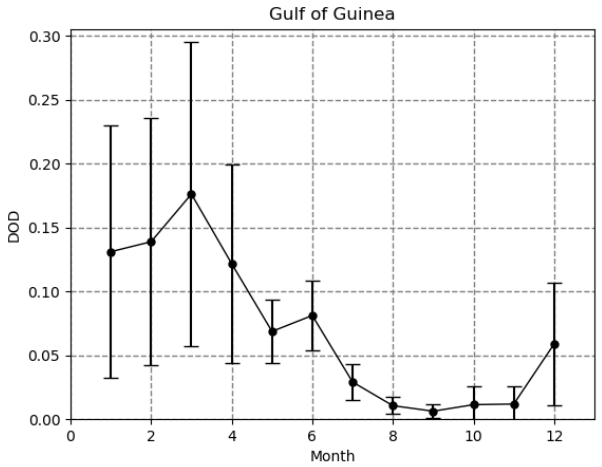


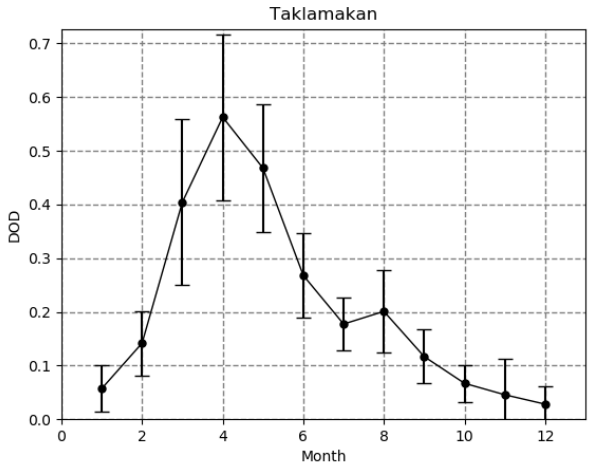


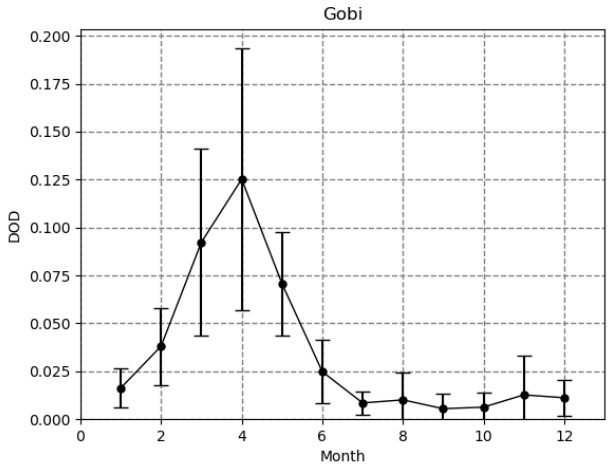




DOD seasonality is quite similar with DAF's (previous slide)…

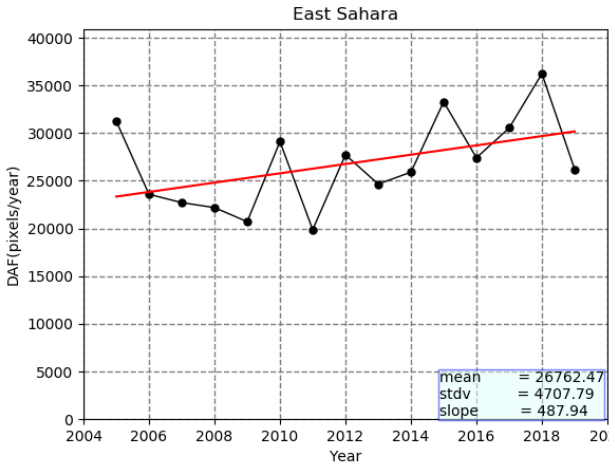


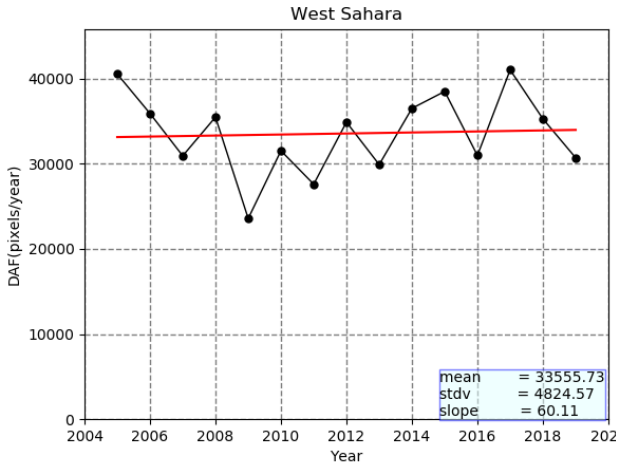


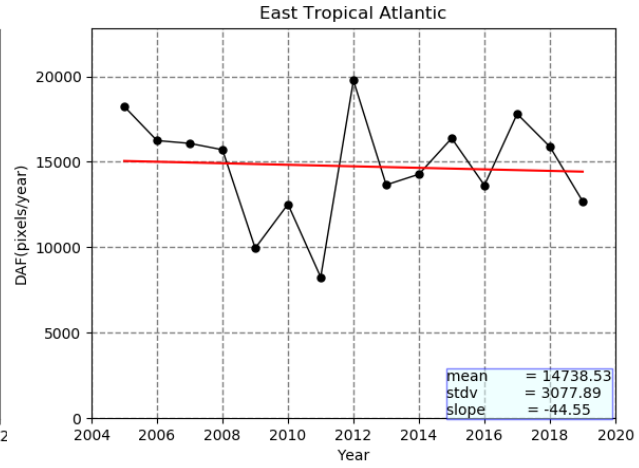


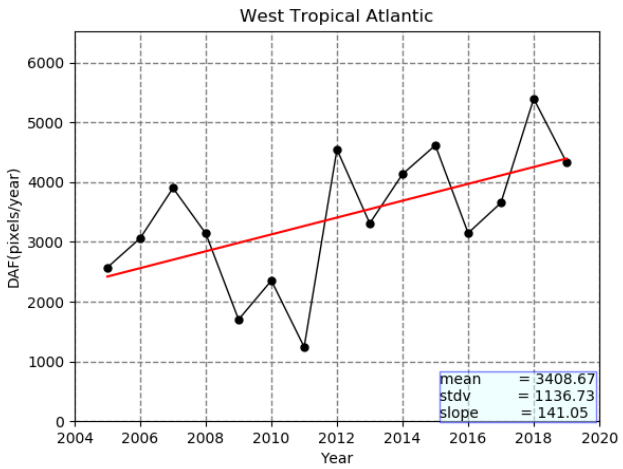
Results

Interannual variability of of the total number of pixels where dust aerosols occurred (Dust Aerosol Frequency, DAF) | Regional

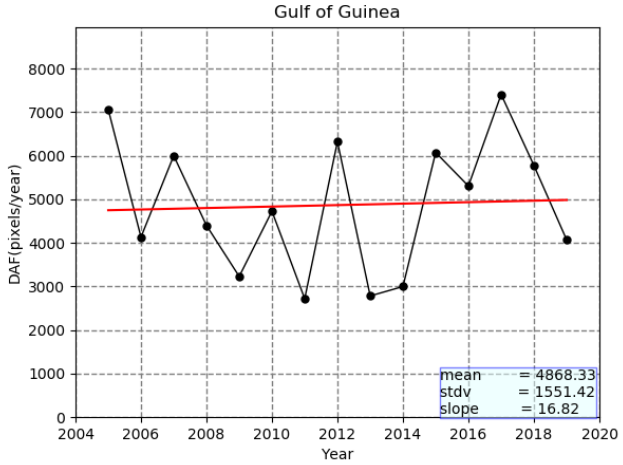


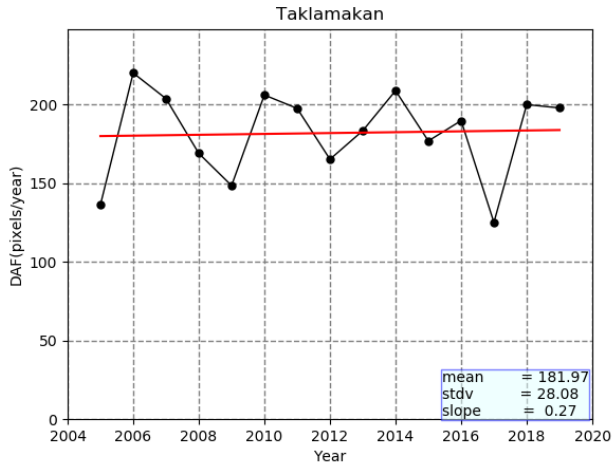


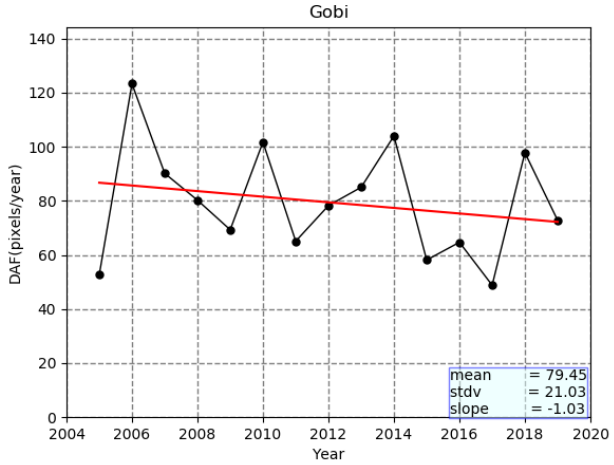




In most of the study regions DAF follows a slight increasing trend during the study period (2005-2019)!

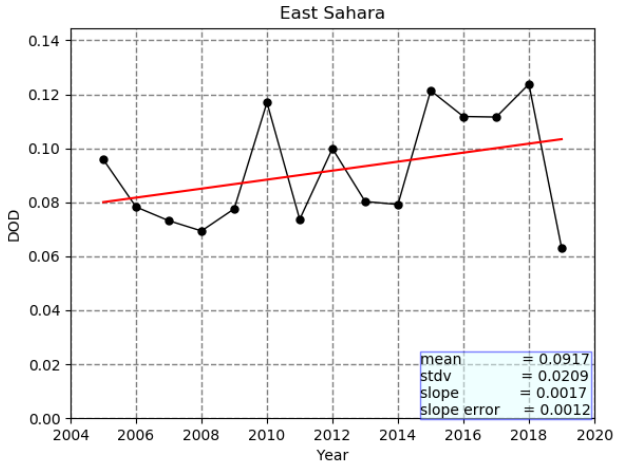


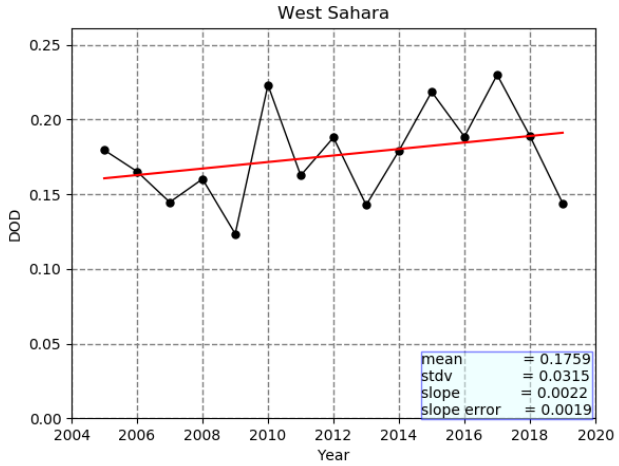


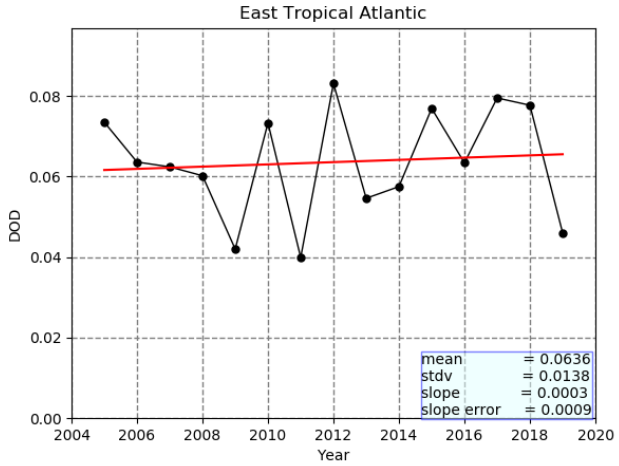


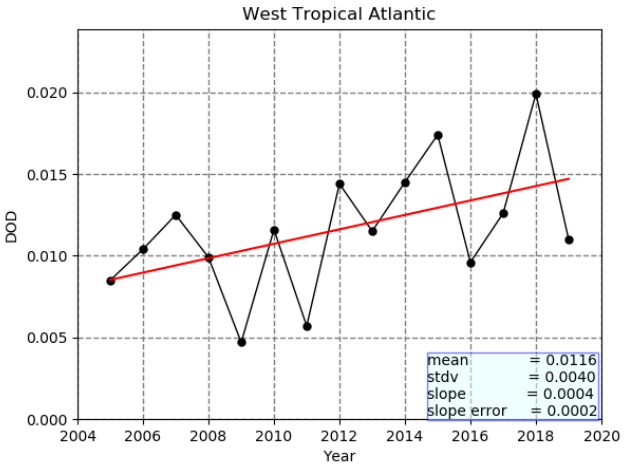
Results

Interannual variability of DOD| Regional

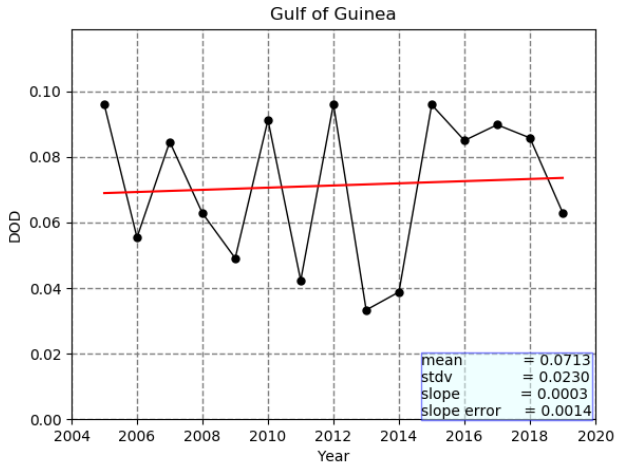


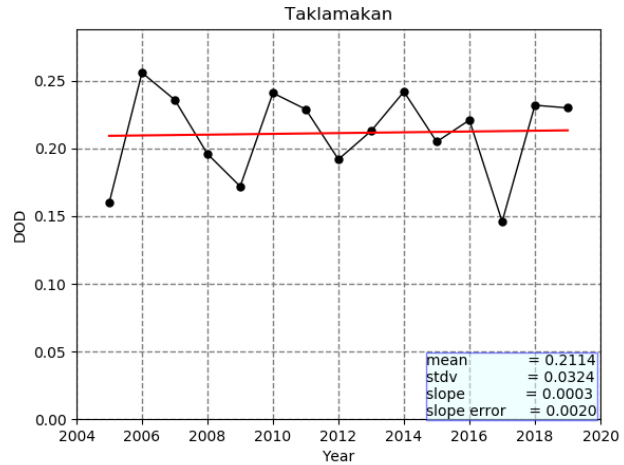


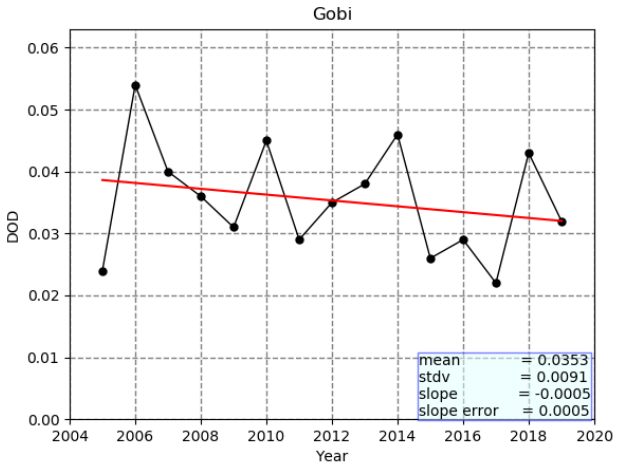




Similar trends appears DOD as well…







Conclusions

- The highest frequencies and DOD values are observed in the Northern Hemisphere, and more specifically across the global dust belt, which extends from the North Africa coasts, to the Middle East, the Central and Southern Asia and through to China
- The global mean values of Dust Aerosol Frequency and DOD are in June and the minimum ones in November
- Similar seasonal cycle (with maximum in summer and or spring and minimum in winter or autumn) is found in almost all of the specific world studied regions
- The values of DAF as well as DOD have increased during the last 15 years, globally and regionally, except for the Asian deserts Taklamakan and Gobi

Perspectives

- The DOD information provided from this study can be used as input to radiative transfer models in order to quantify the DD radiative effects.
- It is planned to compare the algorithm results with reanalysis data (MERRA-2)
- An improved version of the this algorithm, initialized with vertically resolved data (e.g. CALIOP (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations)) is also planned