

# **A climatology of dust episodes in the broader Mediterranean Basin using satellite MODIS C6.1 and OMI OMAERUV data**

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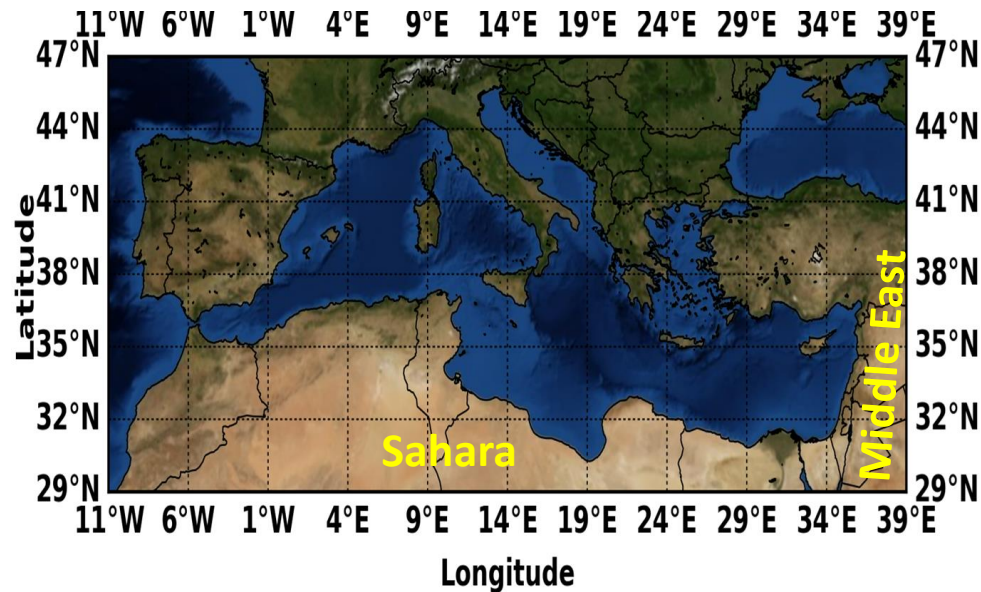
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- **Aerosols** play a key role in determining several **climate and weather processes**, also having effects on others, for example biological or physico-chemical ones. Especially, through their direct, indirect and semi-direct effects, aerosols significantly modify radiation fluxes in the Earth-atmosphere system, thus affecting its radiation and energy budgets
- **Desert Dust (DD) aerosols** is one of the more significant aerosol types, and they are widely investigated, because of their properties and role (high load, absorbing ability, CCN, IN)
- The **effects of DD on weather and climate, but also on other fields**, e.g. transport or energy, are stronger when their loading is higher
- **DD aerosols are frequently transported** far away from their sources (e.g. from Sahara through to the western Tropical Atlantic Ocean, down to the Gulf of Guinea or over the Mediterranean Basin)
- The massive and extended dust transport is well-known as **dust episodes** or events and deserves to be studied

# The study area - Mediterranean Basin (MB)



- The *Mediterranean Basin (MB)* is considered as a *hot-spot* of contemporary and future *climate change*
- It is *very close to some of the major global deserts*, i.e. Sahara and Middle-East, also being surrounded by, and consisted of, areas with variable physico-geographical regimes (natural and anthropogenic or continental and maritime ones)
- Thus, *in the MB several different aerosol types co-exist* (sea salt, biomass burning, desert dust)
- MB is also characterized by diversified climatic regimes and variable cloud types
- Because of its proximity to extended desert areas, it undergoes frequent dust episodes. ***The regime of these episodes, as well as their effects on weather and climate, are worth to be studied under a changing climate. This is attempted in the present study***

## The algorithm

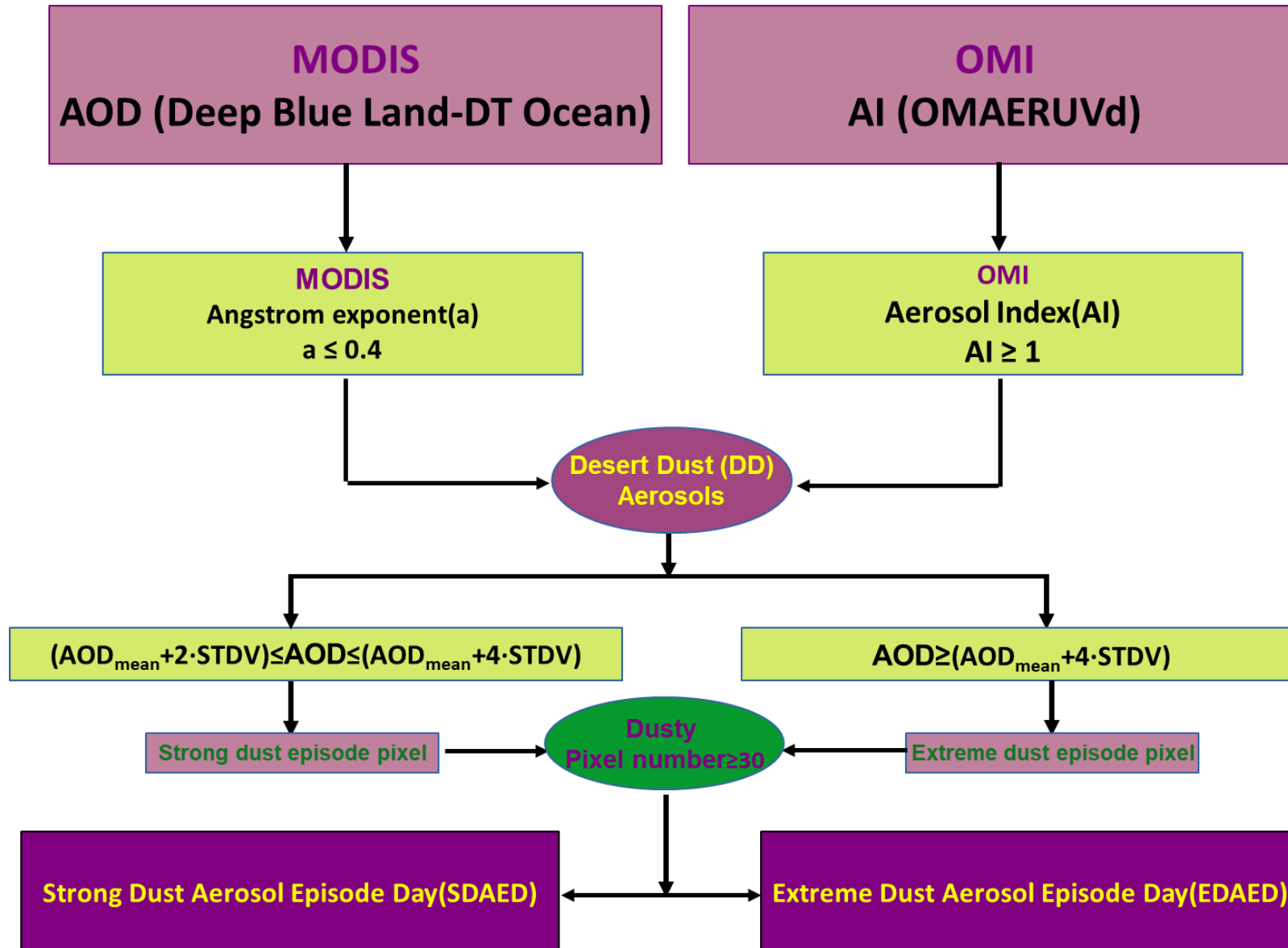
- The algorithm used in this study is a modified version of the algorithm used in the study by **Gavrouzou et al.** (abstract-706, same session of this conference) focusing on the identification of dust particles on global scale
- Apart from the thresholds applied on Angstrom Exponent (a) and Aerosol Index (AI) in order to distinguish between dust and other aerosol types, in this new algorithm version, thresholds are also applied on the following, in order to ensure the presence of dust episodes:
  - a. Aerosol (Dust) Optical Depth (DOD) *in order to ensure the presence of **high DD loads (episodes)** over specific geographical cells (on a 1°x1° latitude-longitude pixel basis)*
  - b. The spatial extension of areas undergoing pixel-level DD episodes, i.e. having overlying atmospheric column dominated by dust, *in order to ensure the existence of **spatially extended dust episodes***

**(a):** The AOD thresholds are calculated on a pixel-level basis, based on the AOD climatological mean values ( $AOD_{mean}$ , calculated over the study period, 2005-2019). Two different thresholds are applied, enabling the identification of **strong and extreme dust episodes**:

$(AOD_{mean} + 2 \cdot stdv) \leq AOD \leq (AOD_{mean} + 4 \cdot stdv)$  - **strong episodes**  
 $AOD \geq (AOD_{mean} + 4 \cdot stdv)$  - **extreme episodes**

**(b):** Regarding the spatial extent of DD episodes, a specific day is characterized as episodic, when the number of episodic pixels (defined based on the above limits) is equal or greater than 30 pixels, it is associated with Mediterranean dusty areas of at least 300.000 km<sup>2</sup>

# The algorithm



Applied on a  
specific day and  
pixel level basis

MODIS (Moderate Resolution Imaging Spectroradiometer)	OMI (Ozone Monitoring Instrument)
<p>Satellite: Aqua Collection: Collection 6.1 Processing Level: Level-3 Temporal Resolution: Daily Spatial Resolution: 1°x1° Spatial Coverage: 11W, 39E, 47N, 29S (Mediterranean Basin, MB)</p>	<p>Satellite: Aura Collection: OMAERUV Processing Level: Level-3 Temporal Resolution: Daily Spatial Resolution: 1°x1° Spatial Coverage: 11W, 39E, 47N, 29S (Mediterranean Basin, MB)</p>
<p>Used Data:  Spectral Aerosol Optical Depth (AOD), 7 wavelengths, above ocean and 3 above land</p>	<p>Used Data:  Aerosol Index (AI)</p>

- First, the climatological mean value of AOD at 550nm as well as the associated standard deviation are calculated, using daily AOD MODIS-C6.1 data for the study period (2005-2019)
- The algorithm ran for every day of the study period, it identified dust, and detected DAEDs on a daily and pixel level basis, based on the exceedance of AOD thresholds
- Spatio-temporal averaging was conducted to produce and study seasonal, annual and inter-annual patterns of strong and extreme DAEDs
- Finally, the episodic days (DAEDs) were grouped into DAECs being consisted of series of  $n$  ( $n \geq 1$ ) DAEDs. This means that  $n$ -sequent episodic days are considered as an episode case (DAEC) with a duration of  $n$ -days

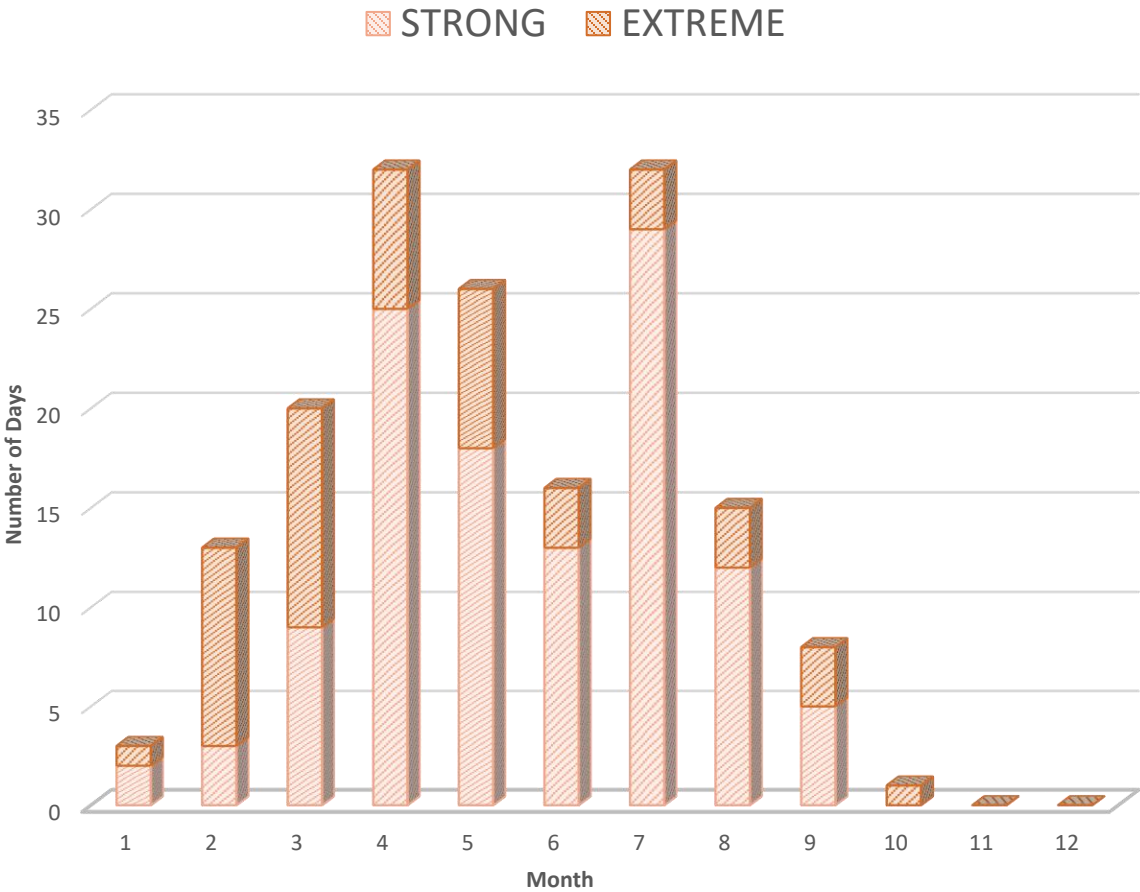


Dust Aerosol Episode Days (DAEDs) | Seasonality

STRONG+EXTREME-EPIISODES	WINTER	SPRING	SUMMER	AUTUMN
DAEDs	16	78	63	9
%	10	47	38	5

STRONG-EPIISODES	WINTER	SPRING	SUMMER	AUTUMN
DAEDs	5	52	54	5
%	4	45	47	4

EXTREME-EPIISODES	WINTER	SPRING	SUMMER	AUTUMN
DAEDs	11	26	9	4
%	22	52	18	8

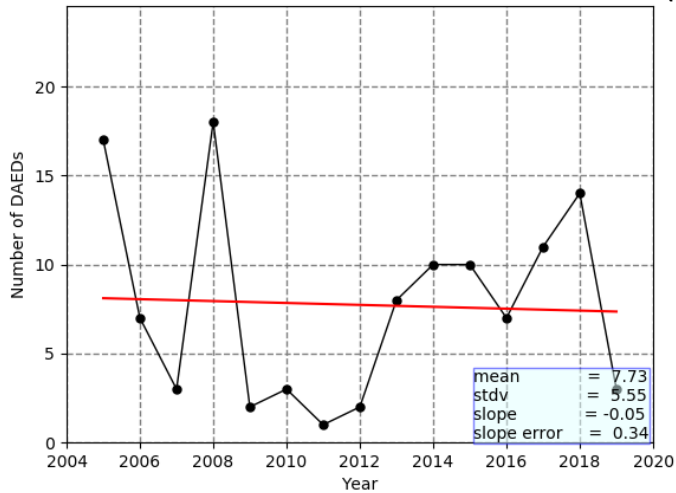


- Most DAEDs are observed in spring and summer
- This seasonality is valid for strong DAEDs, but not for extreme ones
- Most extreme DAEDs take place in spring and winter



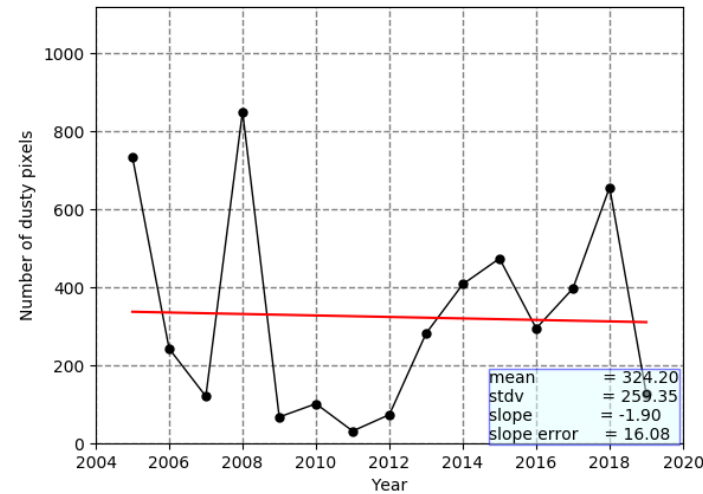
## Dust Aerosol Episode Days (DAEDs) | Inter-annual variability and trends

### Frequency of DAEDs

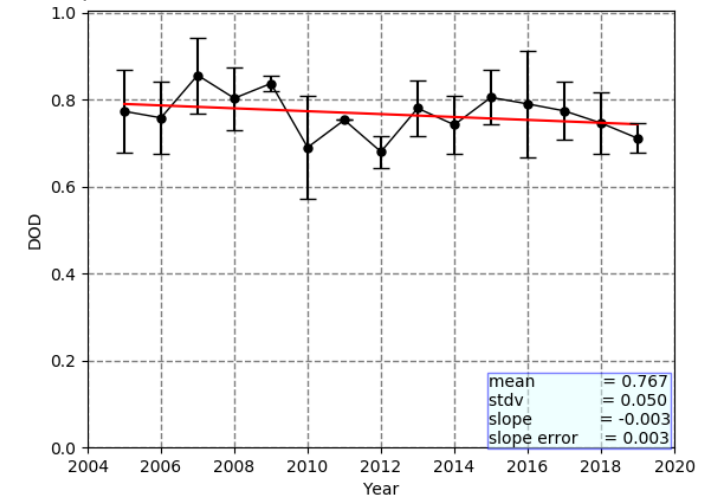


### Spatial Coverage of DAEDs

(accumulated number of dusty pixels of every year's DAEDs)



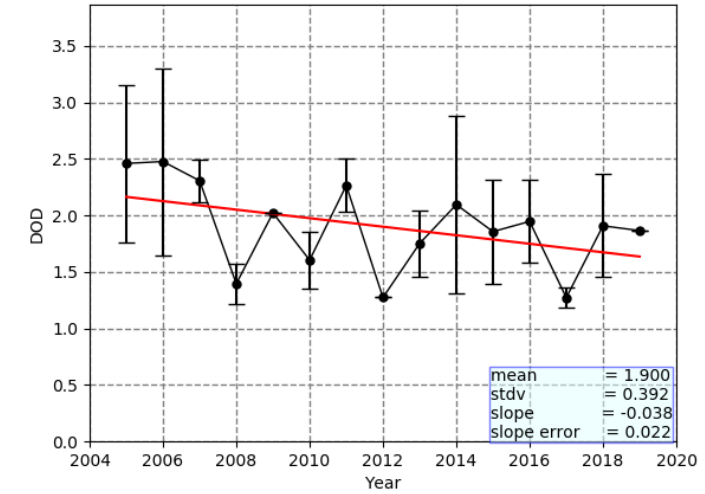
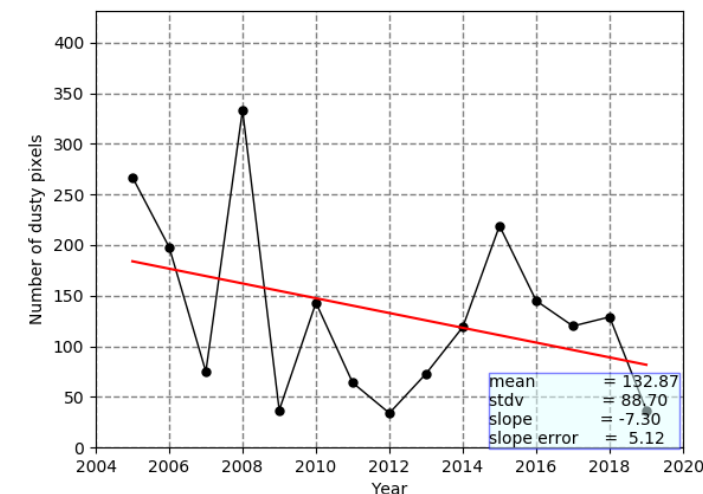
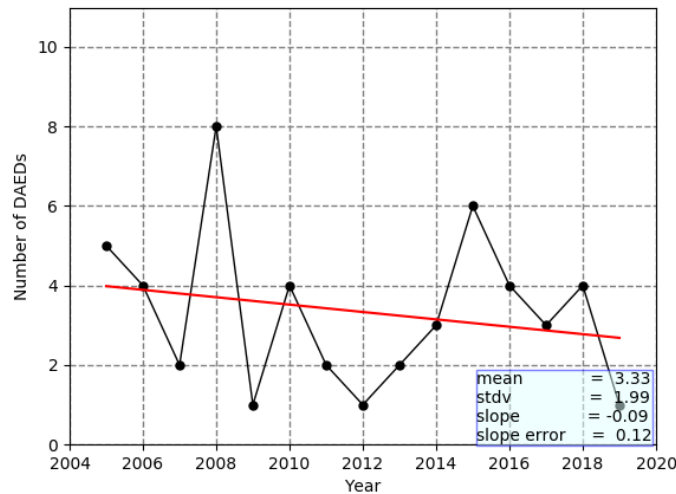
### Intensity of DAEDs



Strong

*DAEDs' number, intensity and spatial extent show slightly decreasing trends ...*

*Most of these trends are not statistically significant!*



Extreme

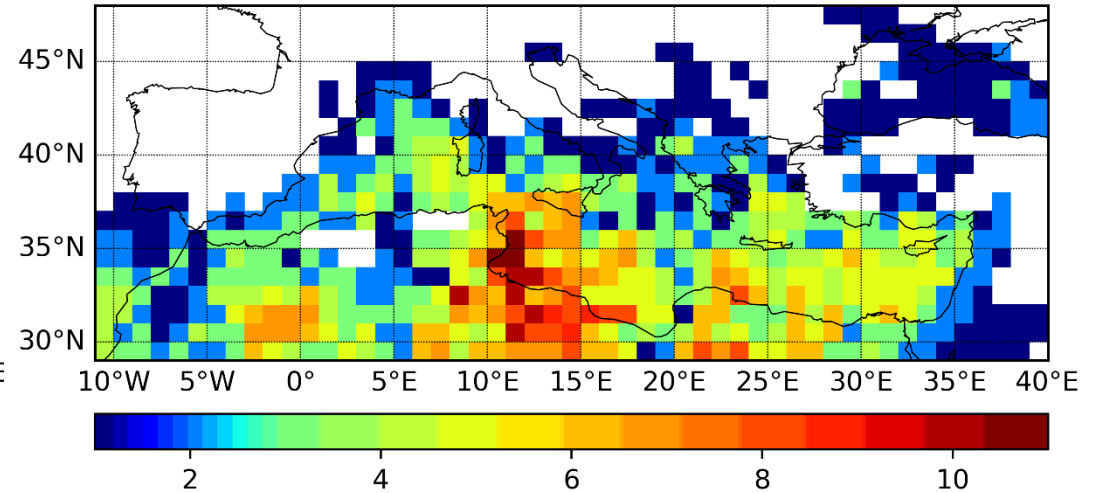
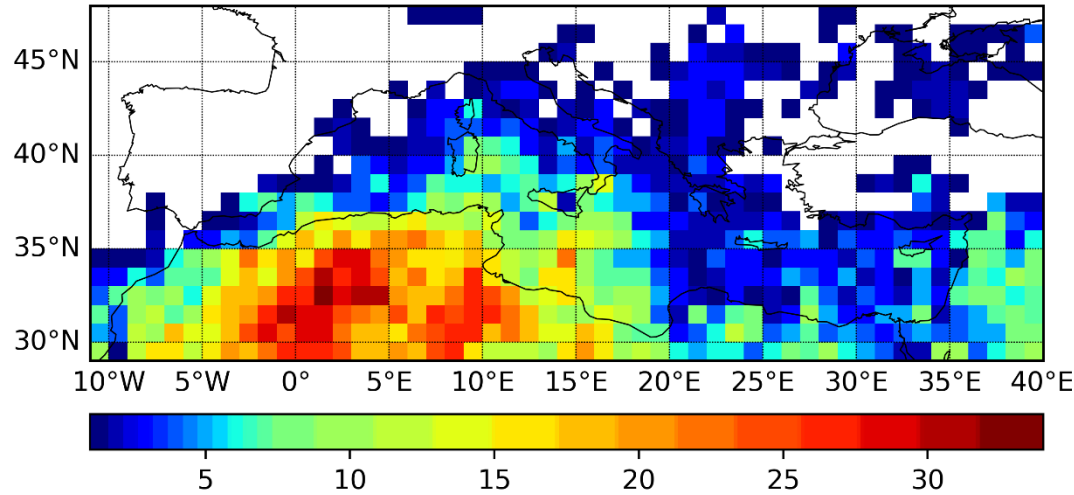
# Results

Climatological (2005-2019) mean annual geographical distributions of dust episodes

Strong

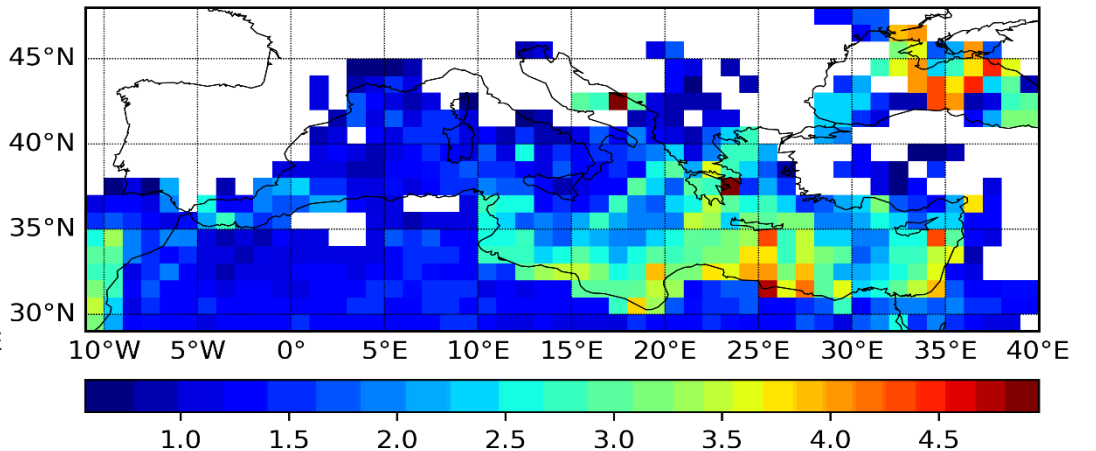
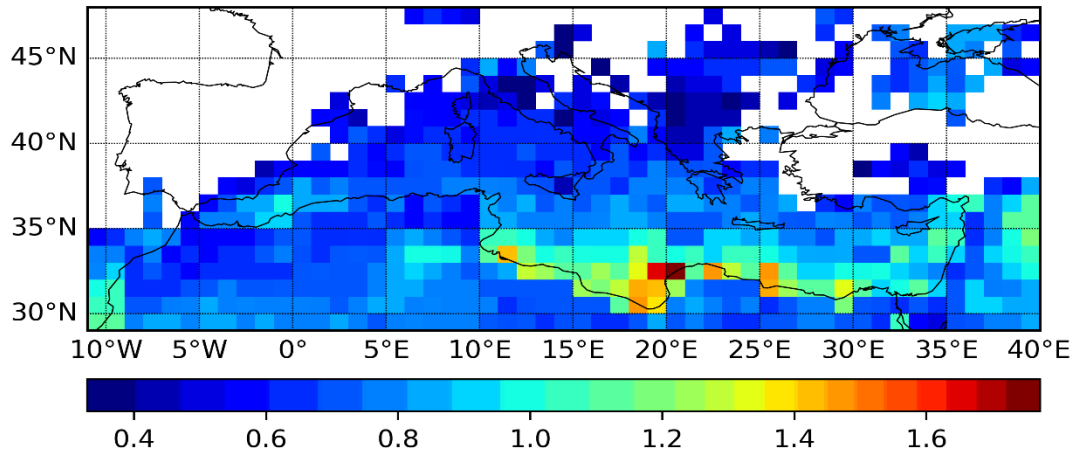
Extreme

Annual number of  
dust episodes of  
DAEDs (days/year)



Episodes of strong DAEDs are more frequent over the western Mediterranean Basin, while the extreme ones over the central and eastern parts of the basin! The most intense episodes are observed along the coasts of Libya and Egypt

DOD



# Results



## Climatological (2005-2019) seasonal geographical distributions of dust episodes | **Strong Episodes**

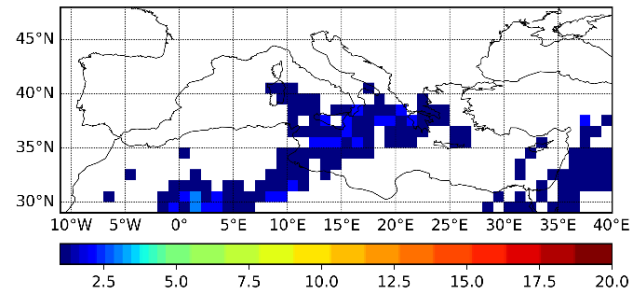
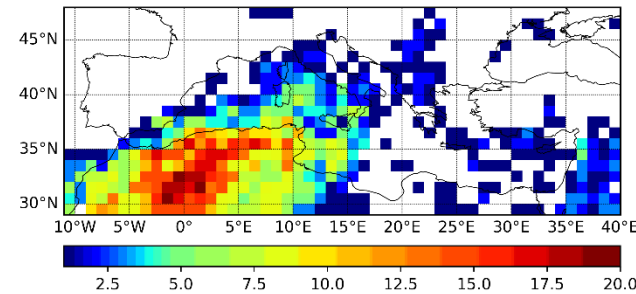
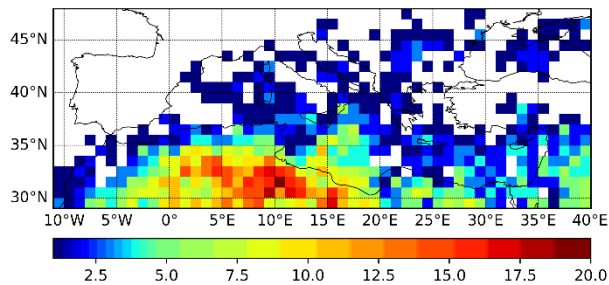
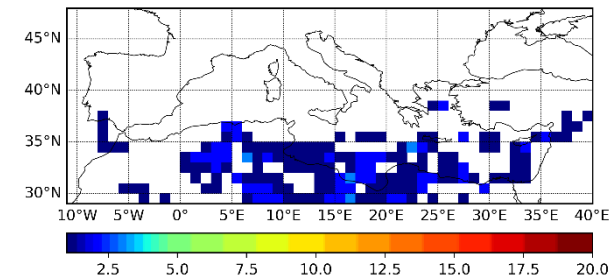
Winter

Spring

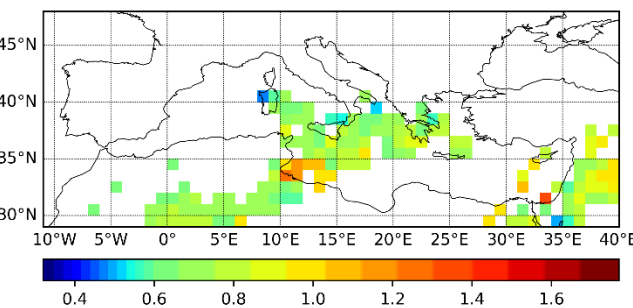
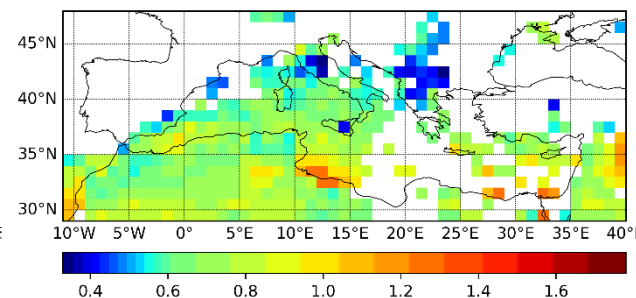
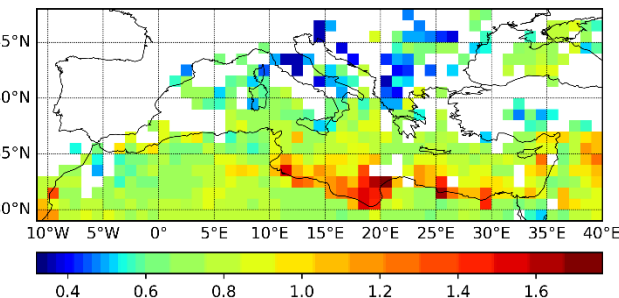
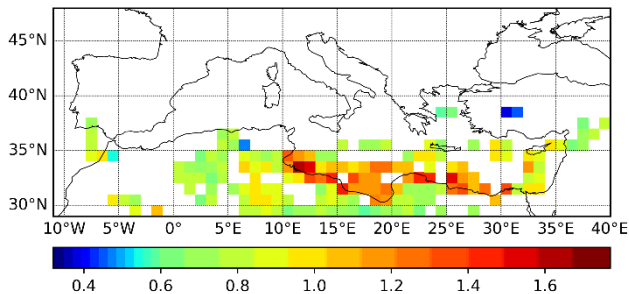
Summer

Autumn

**Number of dust episodes of DAEDs (days/season)**



**DOD**



Episodes of strong DAEDs mainly occur in spring and summer over the western part of the MB  
However, higher DOD values (up to ~1.7) are observed in winter and spring over the central-eastern MB

# Results



## Climatological seasonal mean spatial distributions | Extreme Episodes

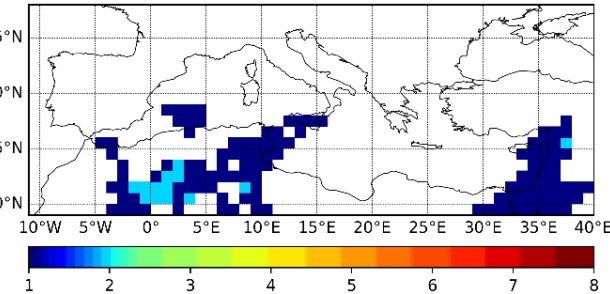
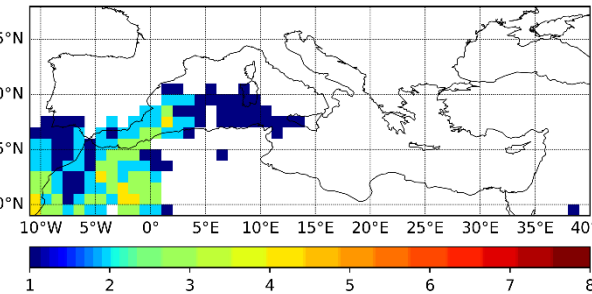
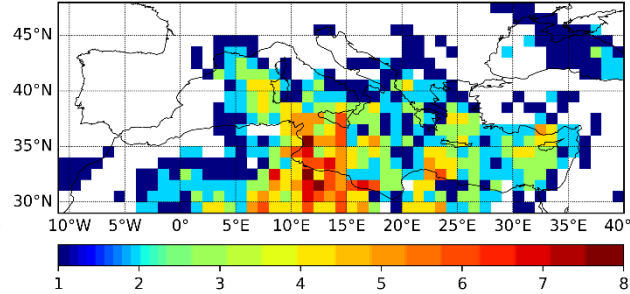
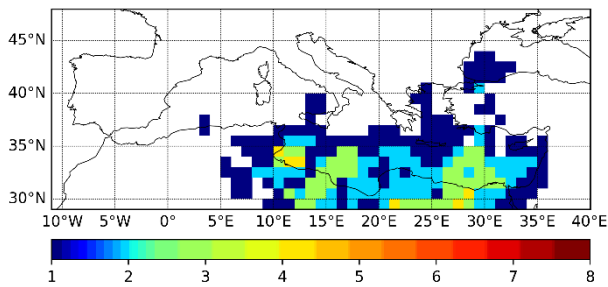
Winter

Spring

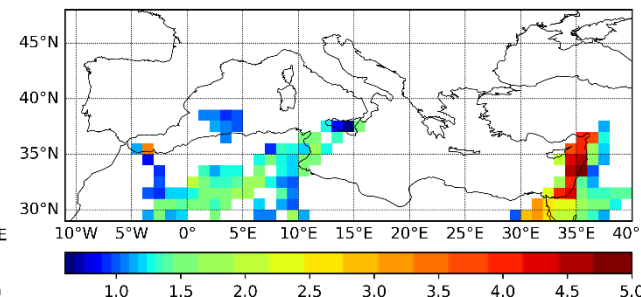
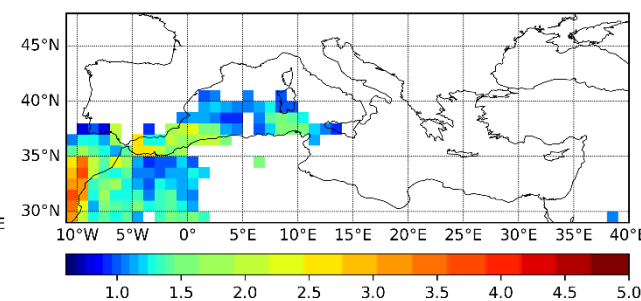
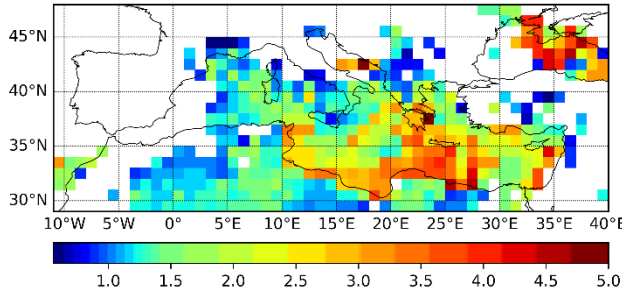
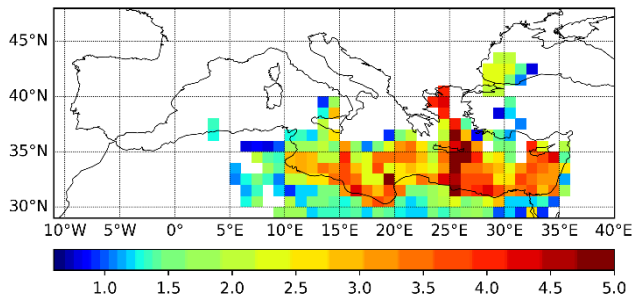
Summer

Autumn

Number of extreme episodes of DAEDs (days/season)

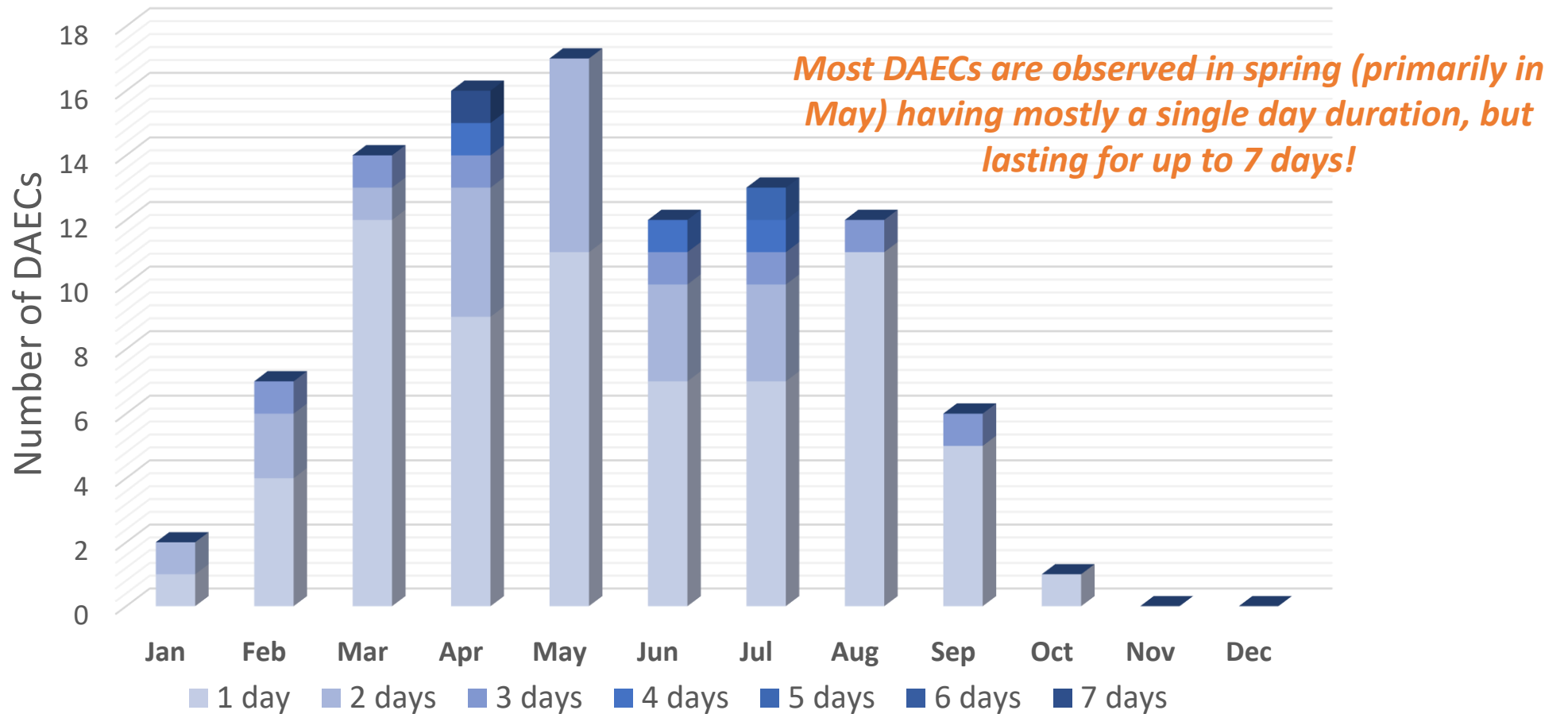


DOD



Extreme DAEDs mainly occur in spring over the central part of the MB

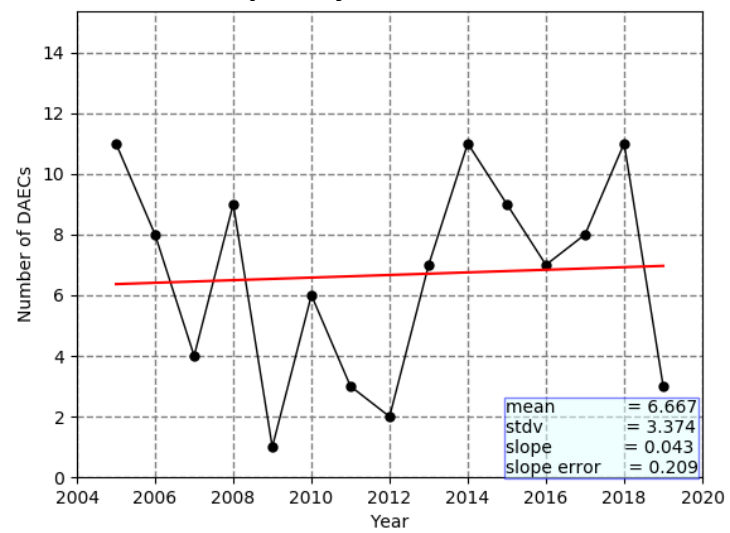
Maximum DOD values (up to ~ 4 - 5) are observed in winter and spring over the eastern MB



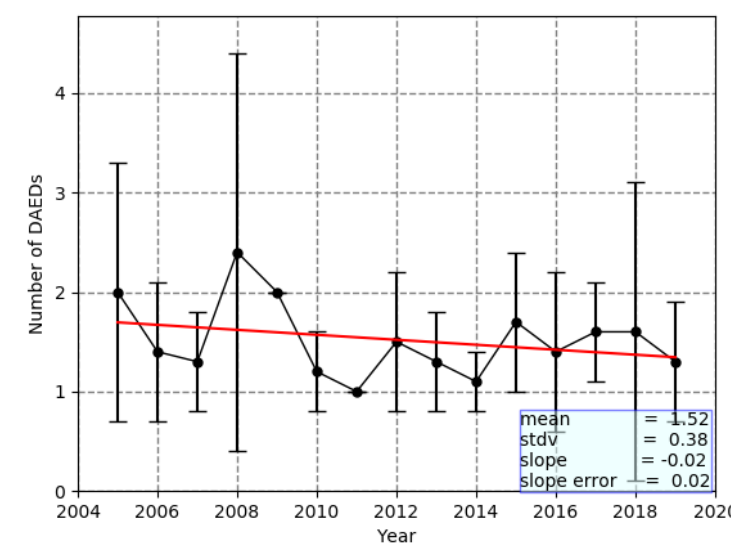
# Results

## Dust Aerosol Episode Cases (DAECs) | Inter-annual variability and trends

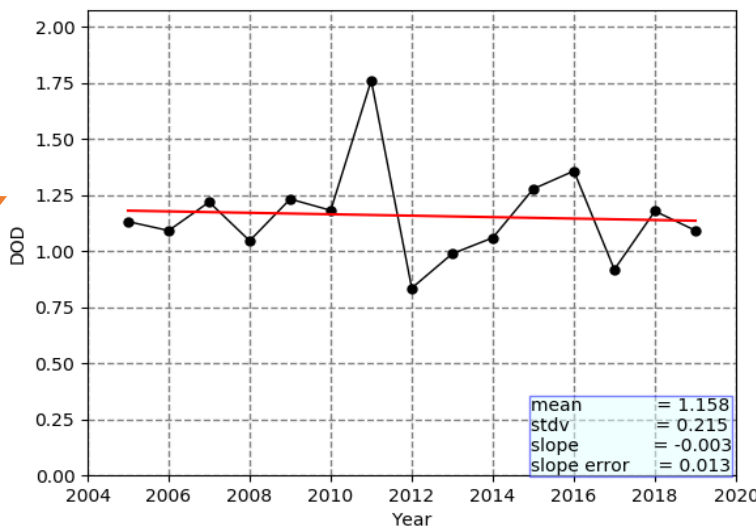
Frequency of DAECs



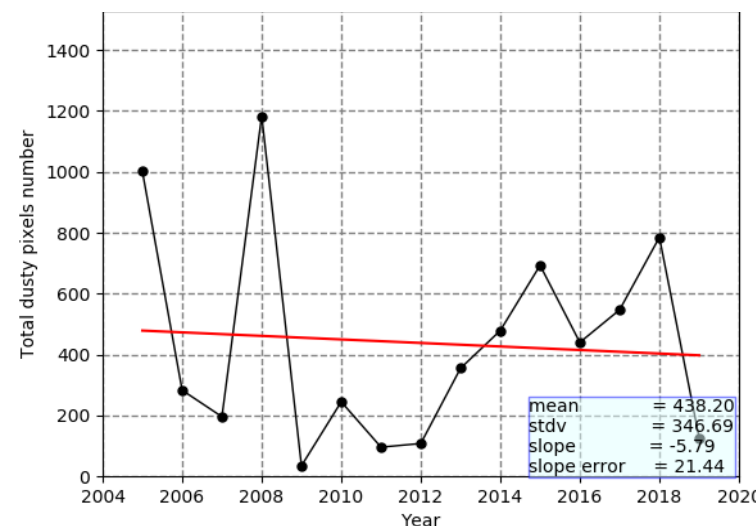
Mean duration of DAECs



Mean intensity of DAECs



Mean spatial extent of DAECs



*Note that only episodic pixels are taken into account when averaging!*



- According to the satellite-based algorithm results, **166 dust aerosol episode days (DAEDs)** took place in the Mediterranean Basin during the last 15 years (2005-2019)
- From these, **116** are characterized as **strong DAEDs** and **50** as **extreme ones**
- Most **strong** DAEDs took place in spring (47%) and summer (38%)
- Most **extreme** DAEDs took place in spring (52%) and winter (22%)
- During the period 2005-2019, **100 Dust Aerosol Episode Cases (DAECs)** have been observed
- The duration of most (66%) DAECs is 1 day and the maximum duration is 7 days
- The majority of **DAECs** occur in **spring (46%)** and **summer (37%)**, while no DAECs are found in November and December
- The number of dust episode days, the number of associated pixels as well as the associated aerosol (dust) loads (DOD) of both strong and extreme DAECs have slightly declined during the last 15 years (not statistically significant change)