Analysis of Sand and Dust Storms (SDS)

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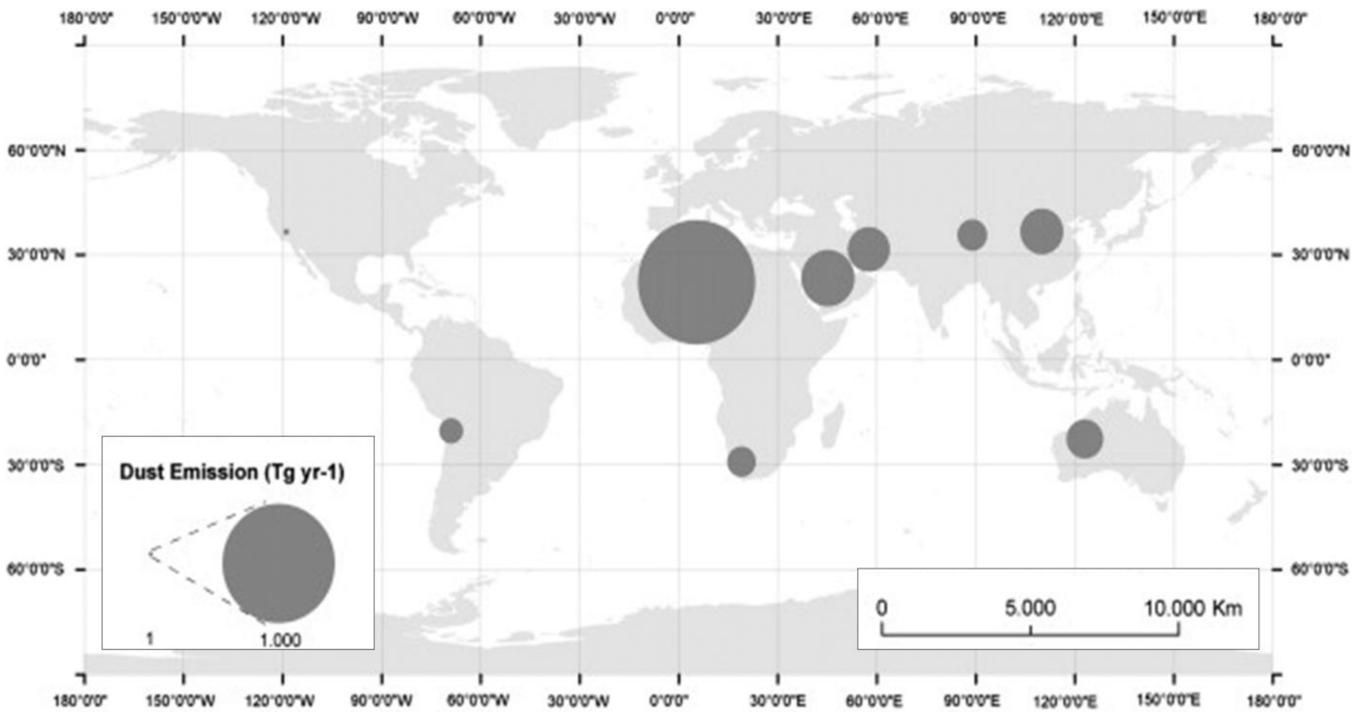
Sand and Dust Storms (SDS)

Approximately 2,000 Tg (2 billion tons) of dust is emitted to the atmosphere from the deserts every year.

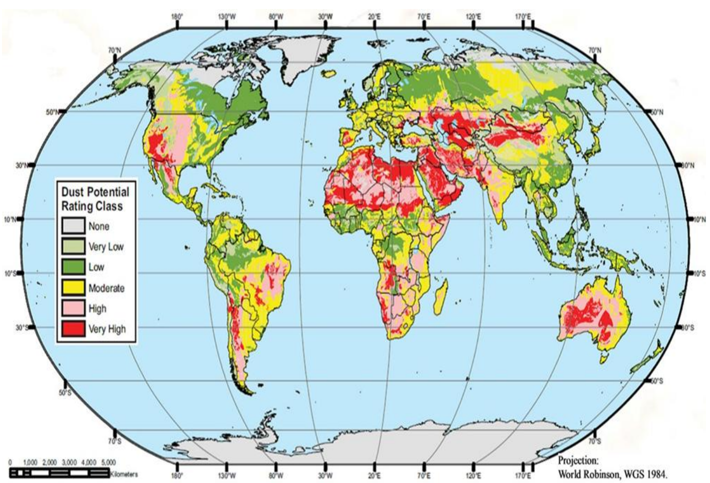
The annual amount of dust released from the Sahara into the atmosphere is about the half of dust released from all sources on Earth, while the dust released from the Sahara and Middle East regions is about 70% of global annual dust emissions.



De Longueville, et al., 2010.

Sand and Dust Storms (SDS)

IPCC accepts mineral dust as a very important component of atmospheric aerosols, one of the main climate variables. According to the IPCC's latest climate predictions, it is expected that sand and dust storms will be more intense as the frequency and severity of the drought has increased.



Global Dust Potential Map. Source: DTF (2013).

BAN Ki-Moon, "Global Assessment of Sand and Dust Storms, UNEP, WMO, UNCCD (2016) ".

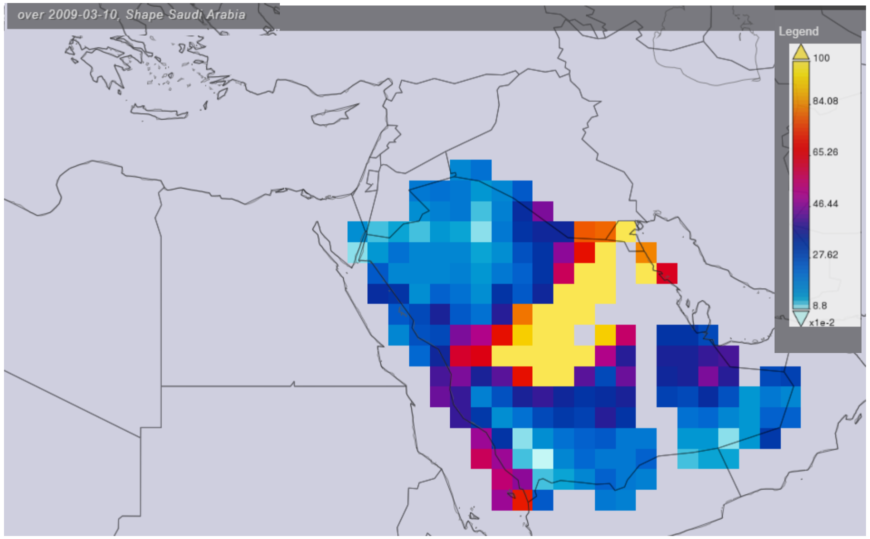
Editor: Gemma Shepherd, UNEP

There is considerable uncertainty about whether SDS are increasing in intensity and frequency and how much is due to human causes. There is also need for greater clarity on the role that climate change is playing and how changes in dust emissions due to land use.

Aerosol Optical Depth (AOD)

Aerosol Optical Depth (AOD) provides important information about the concentration, size distribution, and variability of aerosols (desert dust, sea salt, haze, and smoke particles) in the atmosphere. It is a dimensionless number related to the amount of aerosol distributed within the vertical column of atmosphere over the observation location. AOD provides a quantitative measure of the extinction of solar radiation due to aerosol scattering and absorption. **Heavy dust regions are defined by AOD higher than 0.3. Around deserts, AOD values are above 1.0 and usually below 3.0.**

March 10, 2009 - Riyadh, Saudi Arabia



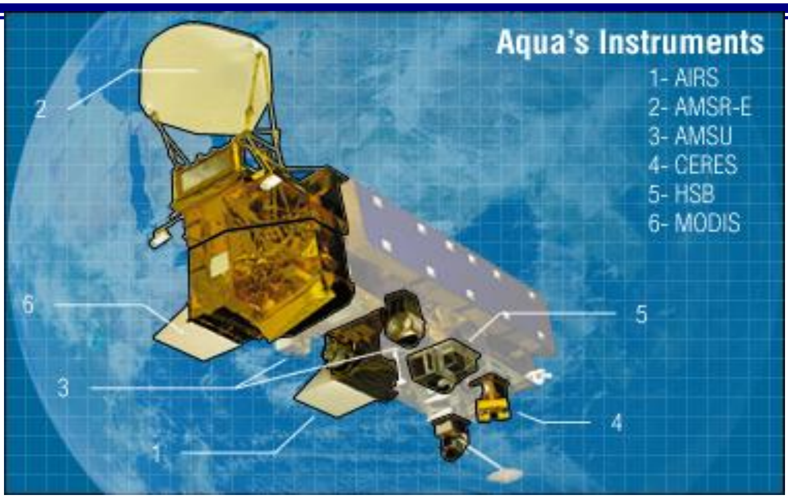
Ground Based AOD Measurements

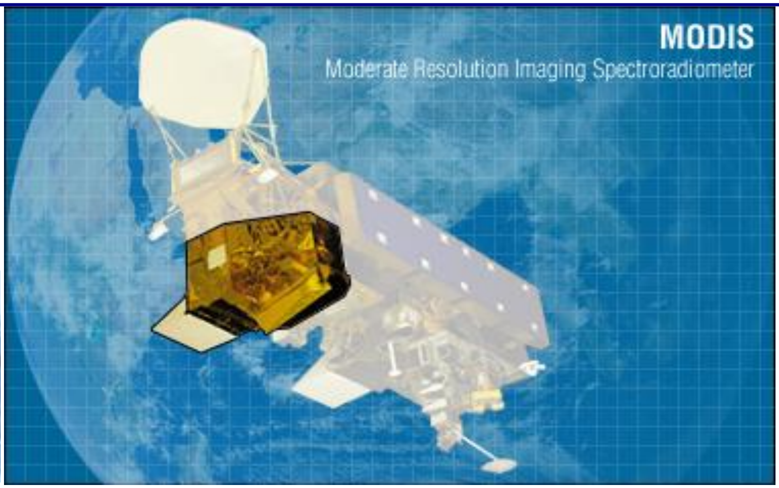
Aerosol Robotic Network (AERONET)

Total Data (Years):	○ All ○ >0.5 ○ >1 ● >2 ○ >3 ○ >5 ○ >7 ○ >10 ○ >15
AOT Level	● Level 1.0 ○ Level 1.5 ○ Level 2.0

Cairo_EMA_2 (30N,31E)	CUT-TEPAK (34N,33E)	Eilat (29N,34E)
IASBS (36N,48E)	IMS-METU-ERDEMLI (36N,34E)	Kuwait_University (29N,47E)
Nes_Ziona (31N,34E)	SEDE_BOKER (30N,34E)	

Satellite Based AOD Measurements





MODIS (Moderate Resolution Imaging Spectroradiometer)

Meteorological Observations

Synoptic Data:

7wwWW -- Present and past weather

ww -- Present weather

- from 06 to 09 Haze, smoke, dust or sand
- from 30 to 35 Sand and Dust Storm
- 98 Heavy thunderstorm with dust storm

The ratio of observed annual data for each station is more than 80 %.

This ratio is more than 90 % for every station for 10 years period.

The missing data is less than 1 % for all observations in study period.

Global & Regional AOD Trends

MODIS and MISR AOD between 2000-2009, *Zhang and Reid, 2010.*

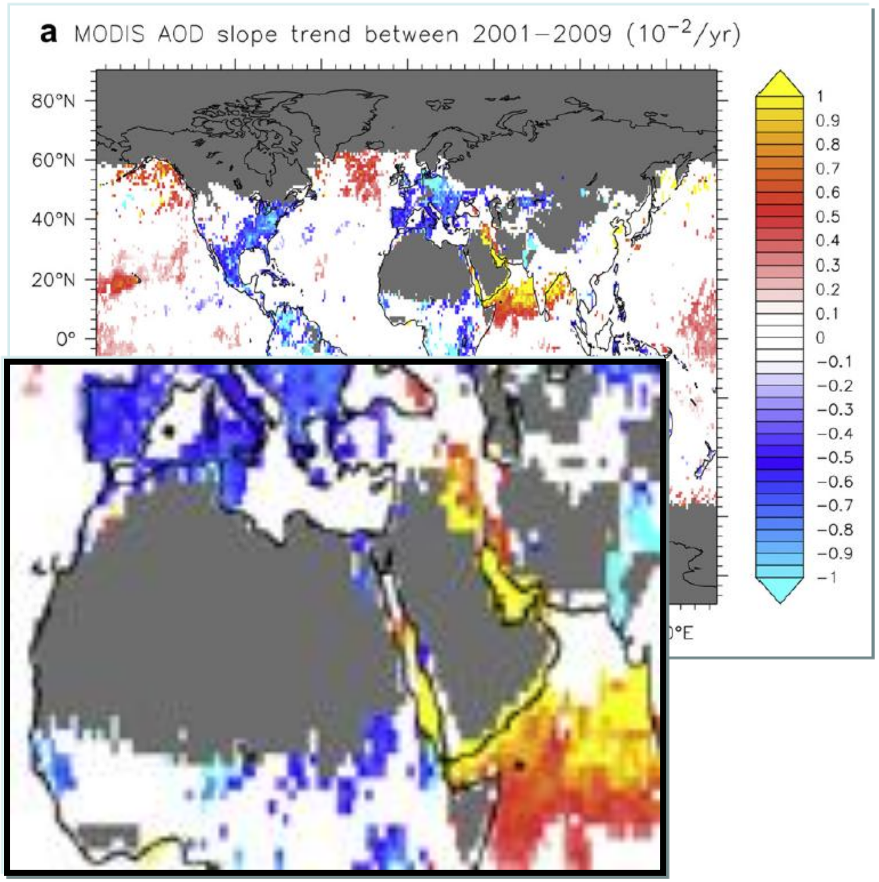
	Latitude (°)	Longitude (°)	Slope AOD/ per decade	$\lvert\omega/\sigma_\omega\rvert$		Corrected slope AOD/ per decade	MISR Slope AOD/ per decade
Global Oceans			0.010	3.60		0.003	−0.003
Africa (NW Coast)	8° N–24° N	60° W–18° W	−0.006	0.61	**- 0.013**	−0.013	−0.035
Africa (SE Coast)	27° S–15° S	32° E–45° E	0.017	2.12		0.010	−0.007
Africa (SW Coast)	23° S–7° S	20° W–15° E	0.016	1.35		0.009	−0.001
Arabian Sea	5° N–23° N	50° E–78° E	0.065	5.40	**0.058**	0.058	0.047
Central America	5° N–20° N	120° W–90° W	−0.016	1.73		−0.023	−0.030
Coastal China	20° N–40° N	110° E–125° E	0.069	4.06	**0.062**	0.062	0.038
Indian Bay of Bengal	10° N–25° N	78° E–103° E	0.076	5.63	**0.069**	0.069	0.035
Mediterranean Sea	30° N–45° N	0° E–40° E	−0.009	0.94	**- 0.016**	−0.016	−0.022
North America (E Coast)	30° N–45° N	80° W–60° W	−0.008	1.07		−0.015	−0.019
Southeast Asia	15° S–10° N	80° E–120° E	0.014	0.80		0.007	0.002

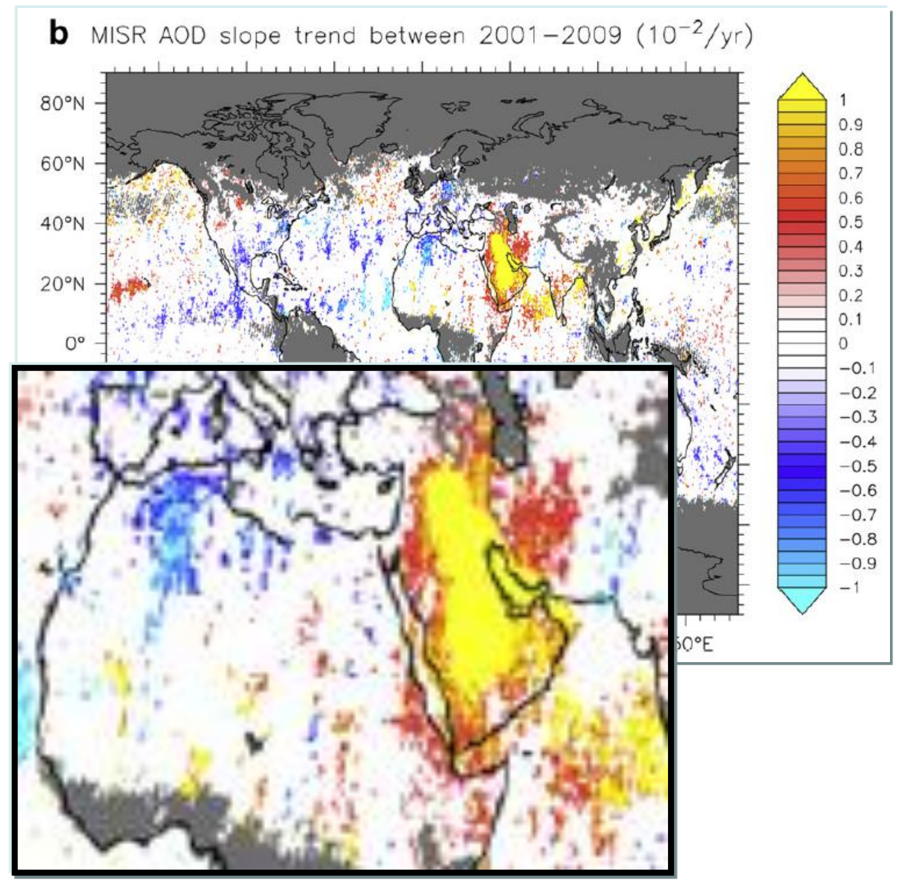
Zhang and Reid (2010) analyzed MODIS and MISR AOD data for the period 2000-2009 over the ocean both global and regional scale. They haven't found significant trend in global (0.003/decade).

On a regional scale the Bay of Bengal (0.07/decade), Asia's eastern coast (0.06/ decade) and on the Arabian Sea (0.06/decade), significant increases were observed.

Global & Regional AOD Trends

Studies made by de Meij et al (2012) also supported increasing aerosol trend over Middle East between years of 2001-2009. There was no important change over Africa.

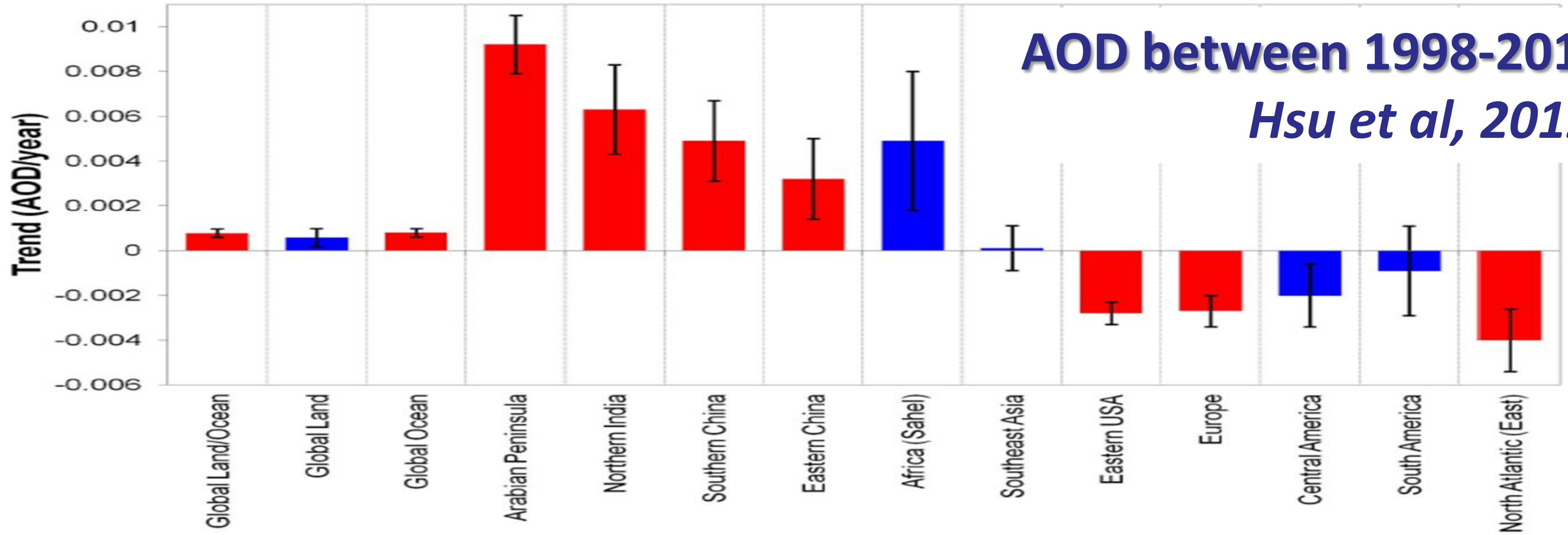


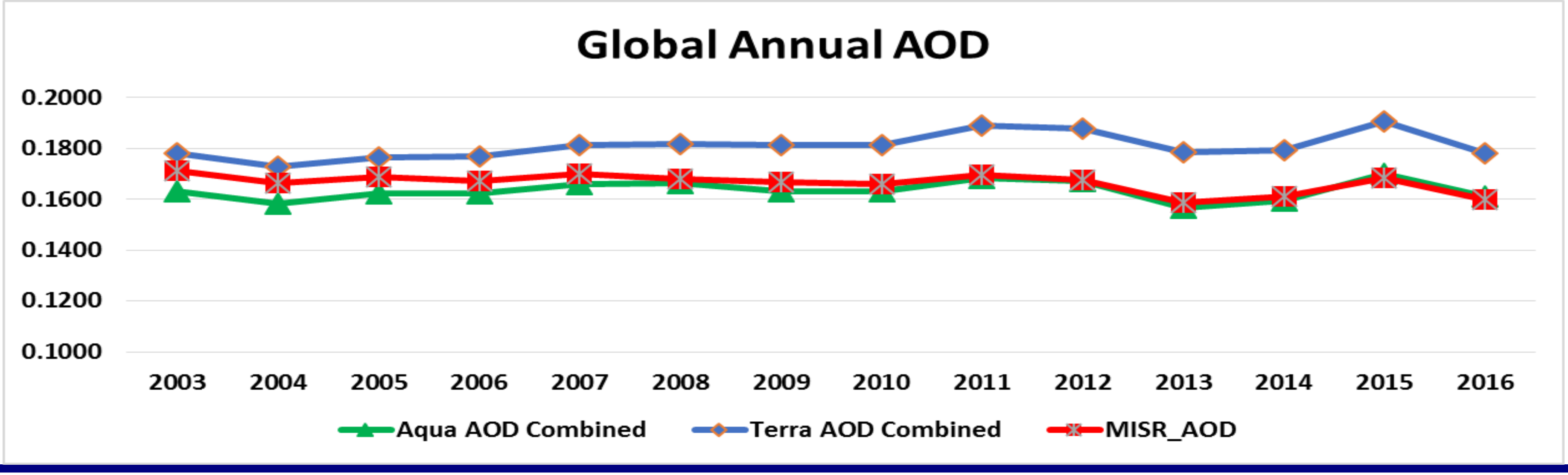


Global & Regional AOD Trends

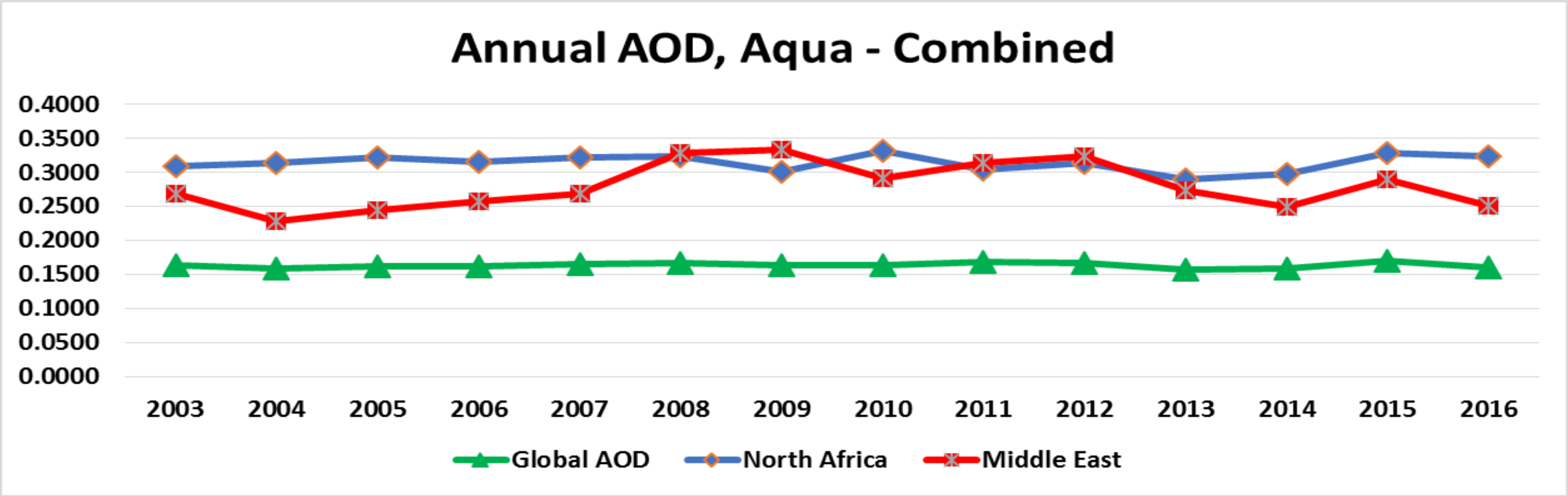
AOD between 1998-2010

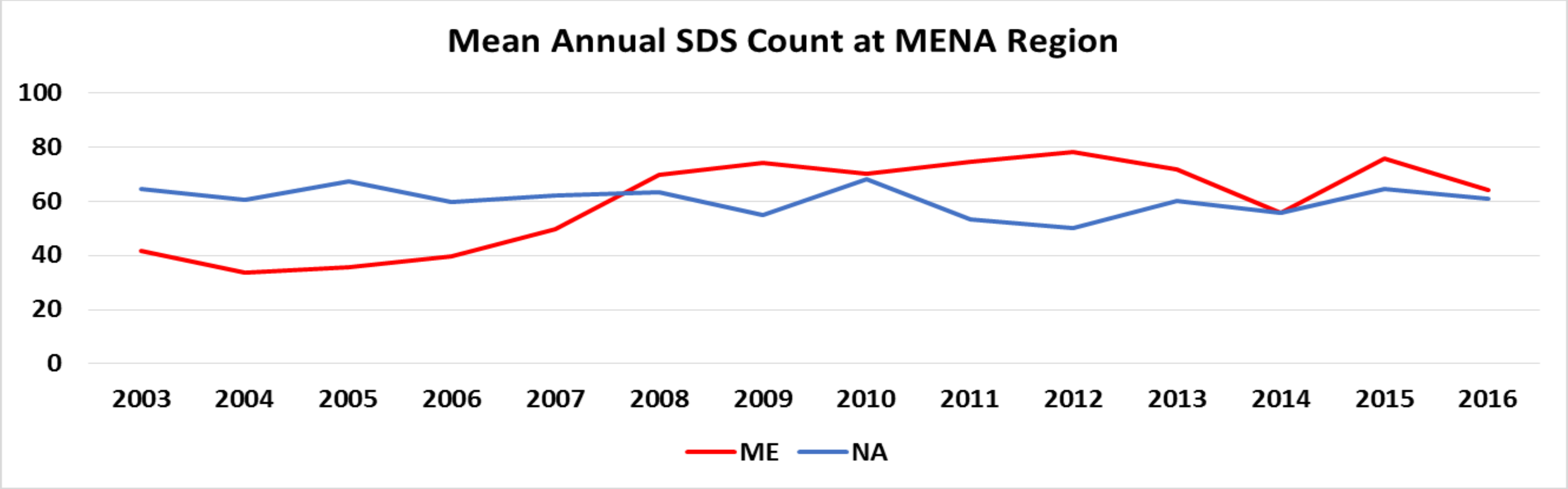
Hsu et al, 2012.



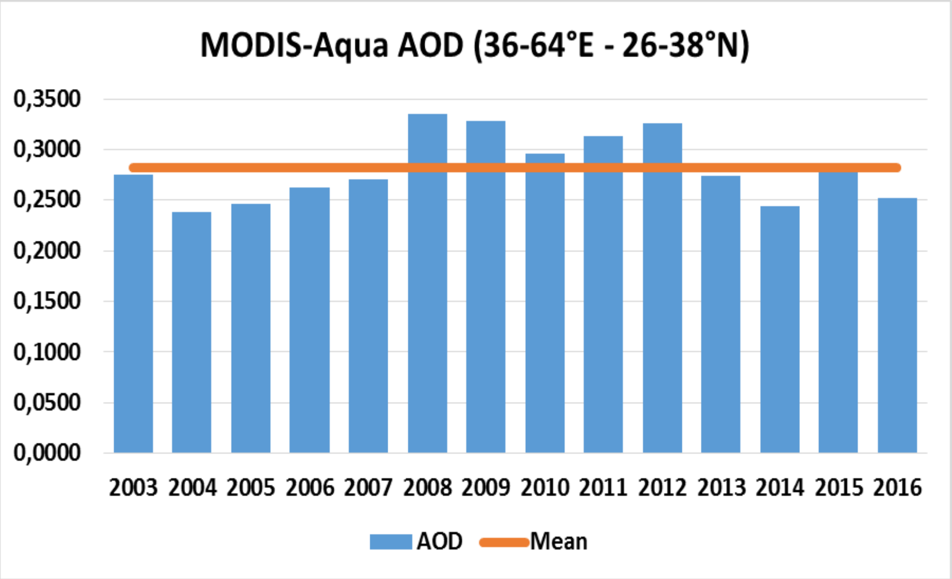


Regional AOD Trends



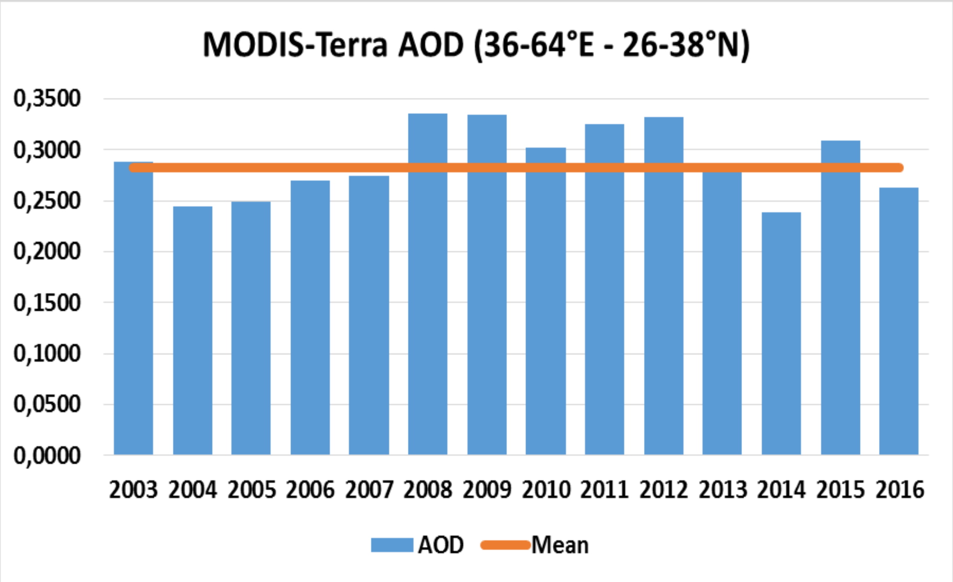


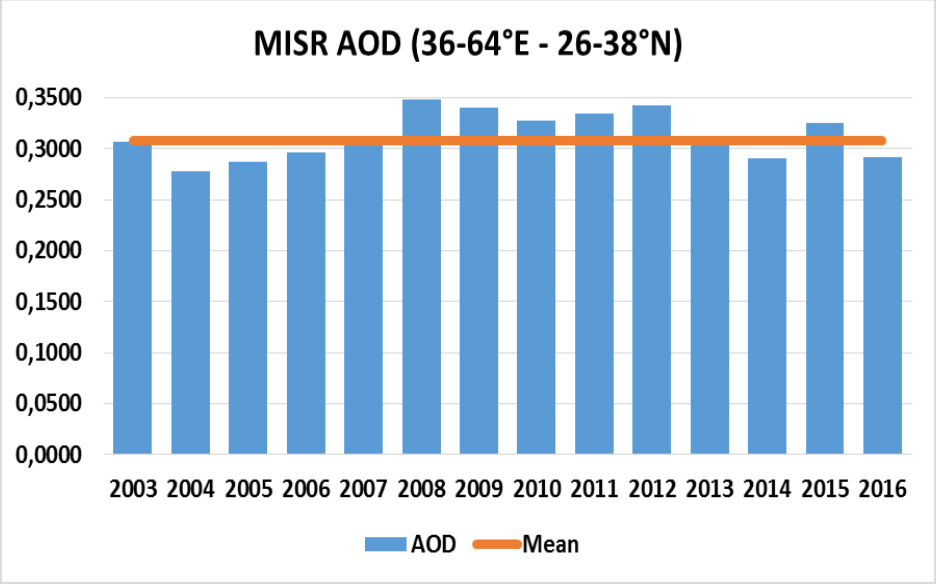
Annual AOD Trends in Middle East



For the last 4 years (2013-2016), annual mean AOD is comparably lower than the previous period due to the 3 different satellite measurements.

The values are the highest between 2008 and 2012.

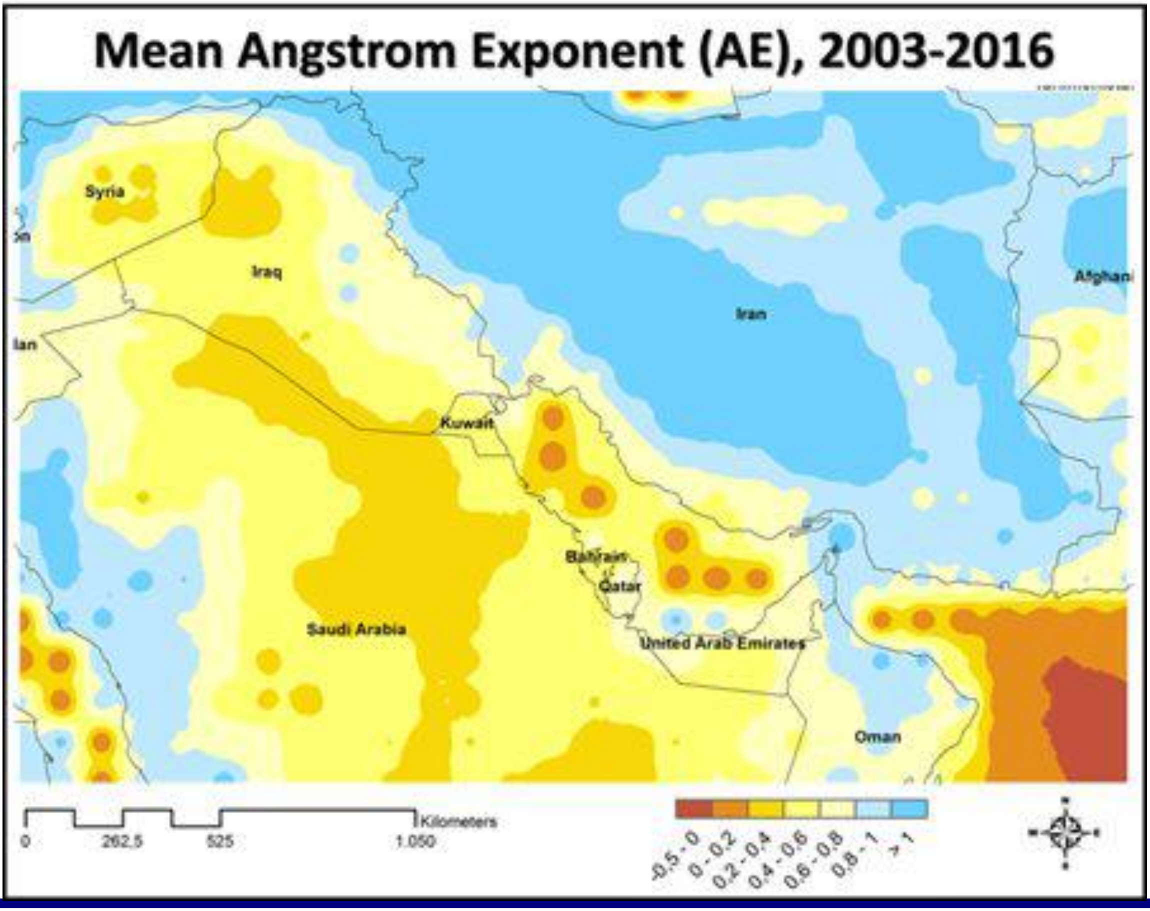




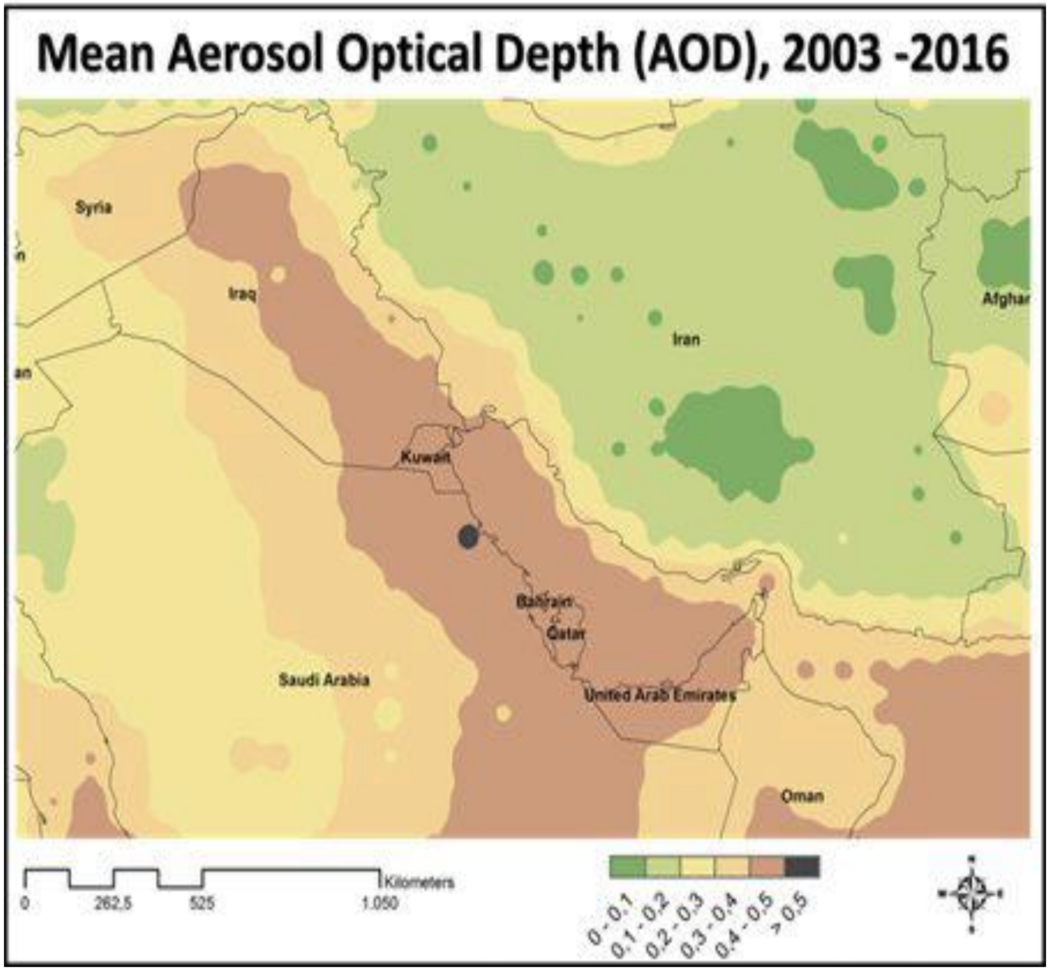
Angstrom Exponent (AE)

The Angstrom Exponent (AE) is an exponent that provides additional information on the particle size, aerosol phase function and the relative magnitude of aerosol radiances at different wavelengths.

It is inversely related to the average size of the particles in the aerosol: the smaller the particle size, the larger the Angstrom Exponent is. Therefore, low AE values indicate strong presence of coarse aerosols relating to the dust events.



SDS Analysis over Middle East



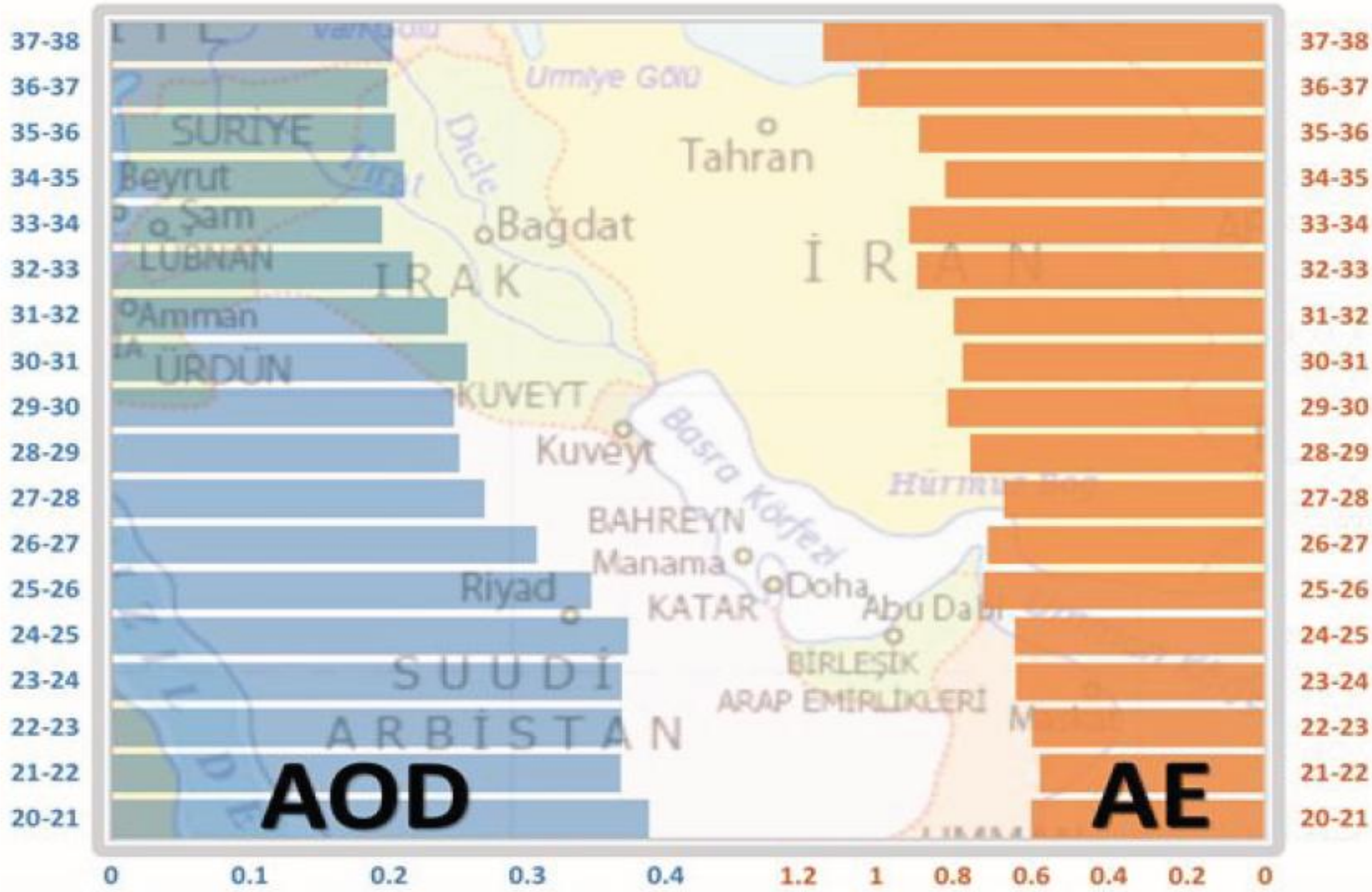
Mean AOD of the period 2003-2016 illustrates high AOD values reaching up to 0.5 over east of Saudi Arabia, Kuwait, Bahrain, Qatar, Iraq and Persian Gulf.

Low AE values are observed over Saudi Arabia, Iraq, Syria and lowest ones over Persian Gulf.

Those areas with low AE and high AOD point out dust storms.

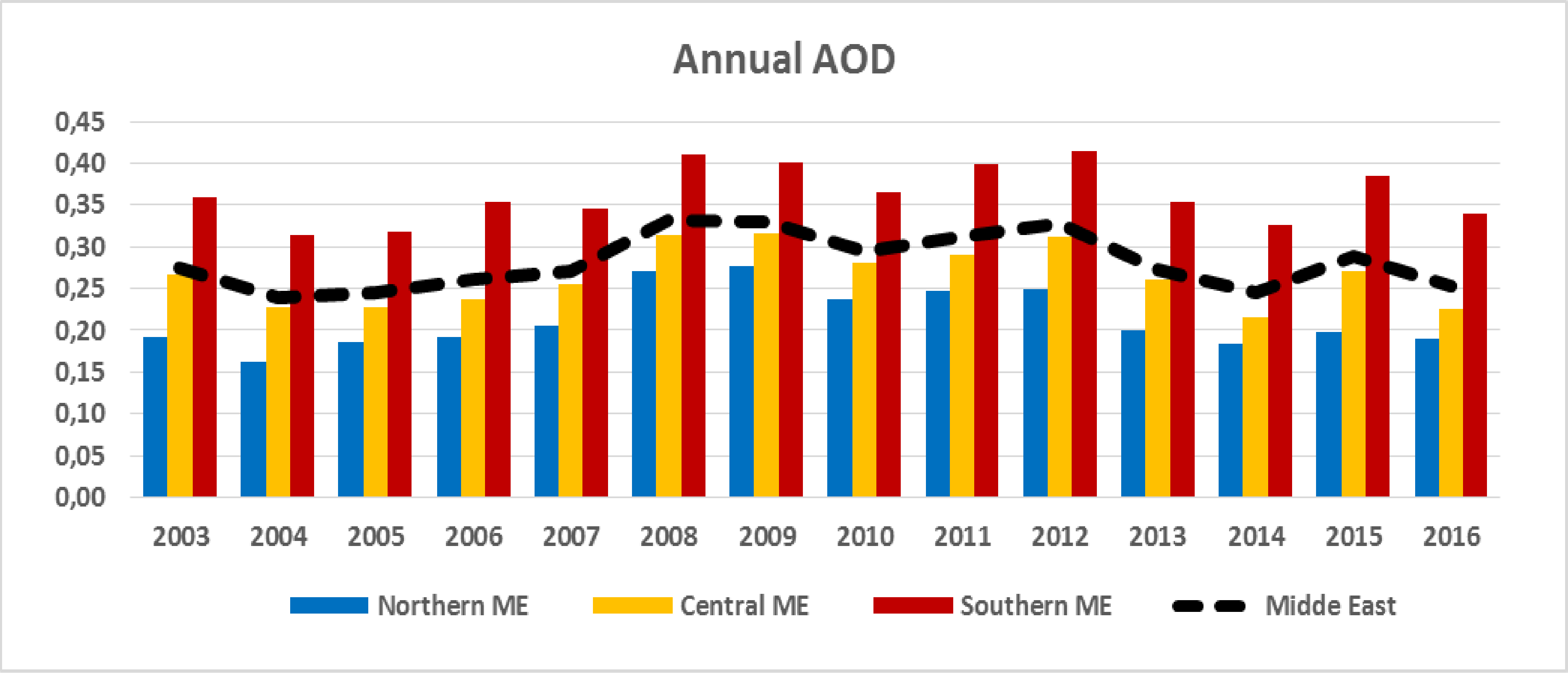
Spatial AOD and AE Variation in ME

Moving southward along 38-20N latitudes, there is a significant increase in AOD values, accompanied by a decrease in AE values (coarse particles) in the same direction.



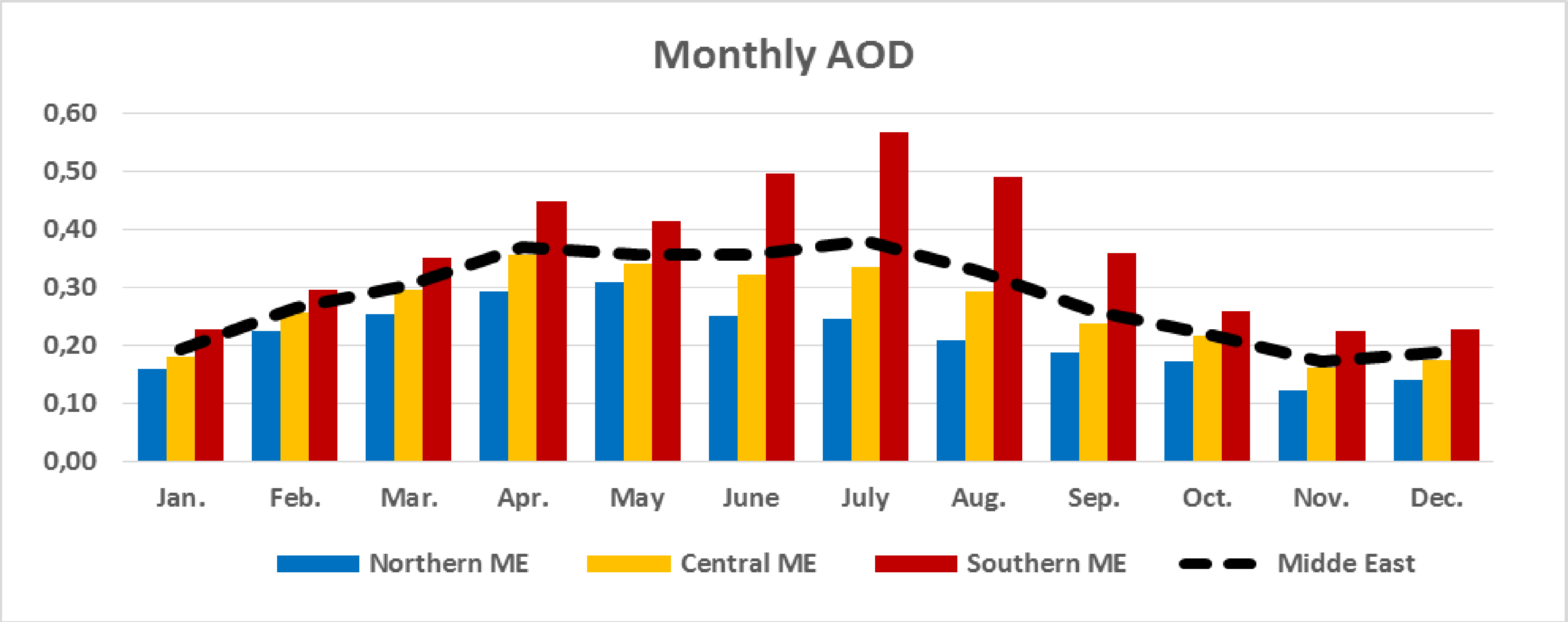
Annual AOD Trends in Middle East

Annual AOD values of the Central Middle East almost follow the averaged values of the Middle East Region as expected, while higher values of AOD are observed in the Southern ME.



Seasonal AOD Variation in Middle East

The highest AOD in the Northern and Central Middle East are in spring. On the other hand, the Southern Middle East exhibits a different seasonal pattern with a maximum AOD value in July.



Extreme Daily AOD Analysis

*Gkikas, A., Hatzianastassiou, N., and Mihalopoulos, N.: **Aerosol events in the broader Mediterranean basin based on 7-year (2000–2007)** MODIS C005 data, Ann. Geophys., 27, 3509– 3522, doi:10.5194/angeo-27-3509-2009, 2009.*

$$AOD_{Threshold} = \overline{AOD} + i \times \sigma_{AOD}, i = 1,2,3,4 \quad (1)$$

$$\overline{AOD} + 2 \times \sigma_{AOD} \leq AOD < \overline{AOD} + 4 \times \sigma_{AOD} \quad \text{strong aerosol event} \quad (2)$$

$$AOD \geq \overline{AOD} + 4 \times \sigma_{AOD} \quad \text{extreme aerosol event} \quad (3)$$

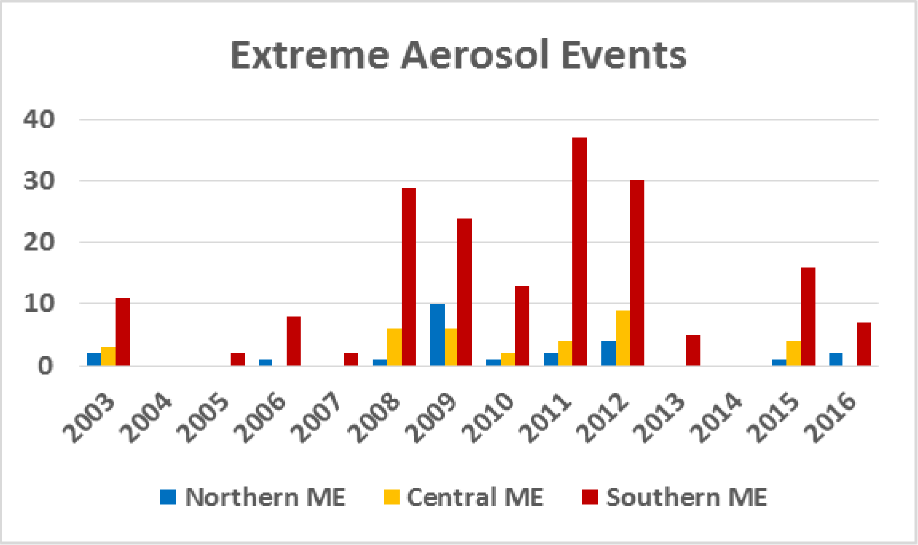
Dust (mainly from Sahara and less from Middle-East) is the most important source of particulate matter in the Mediterranean Basin and its transport is usually associated with large AODs (Barnaba and Gobi, 2004).

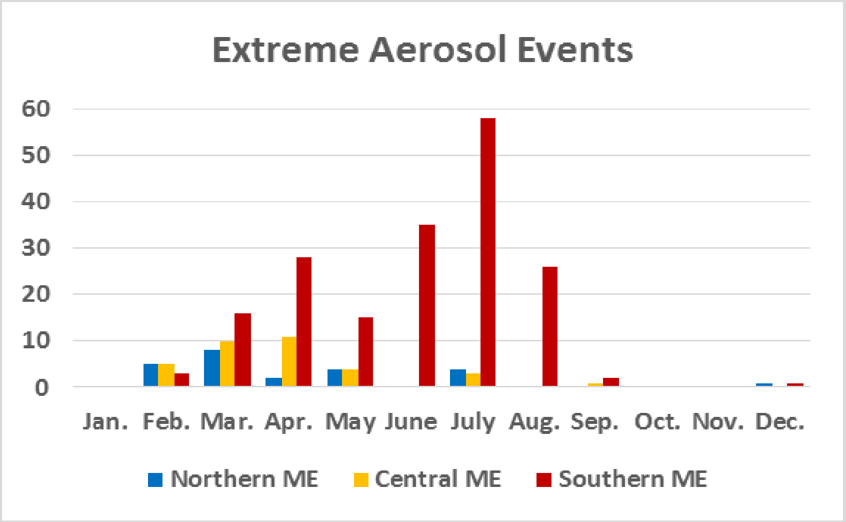
Therefore, extreme aerosol episodes should be associated with dust.

Extreme and Strong Aerosol Events

By using threshold values of AOD, extreme and strong aerosol events were calculated (Gkikas et al., 2009).

Extreme aerosol events point out dust storms while strong aerosol events are linked to sea salt, forest fires and anthropogenic activities.



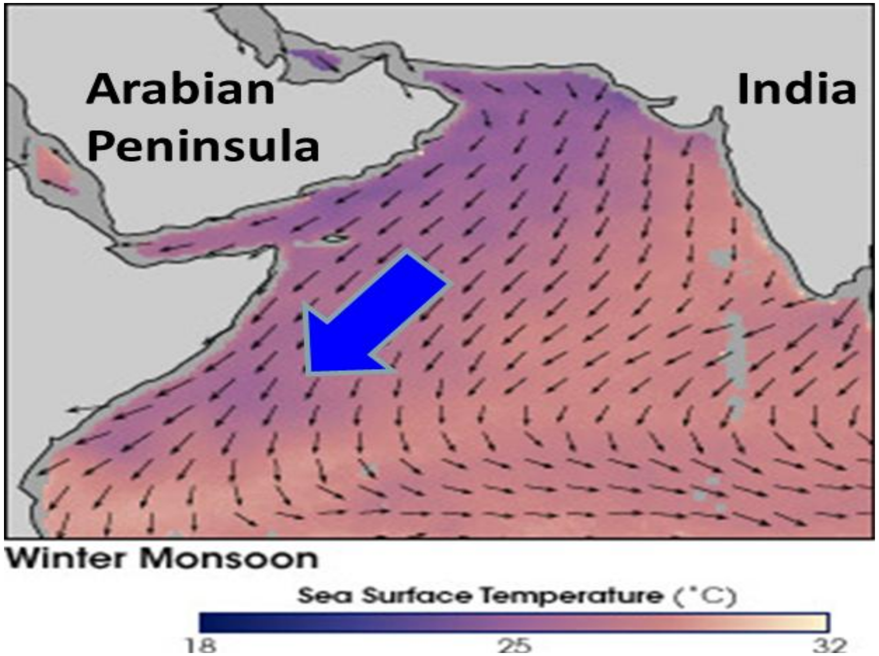


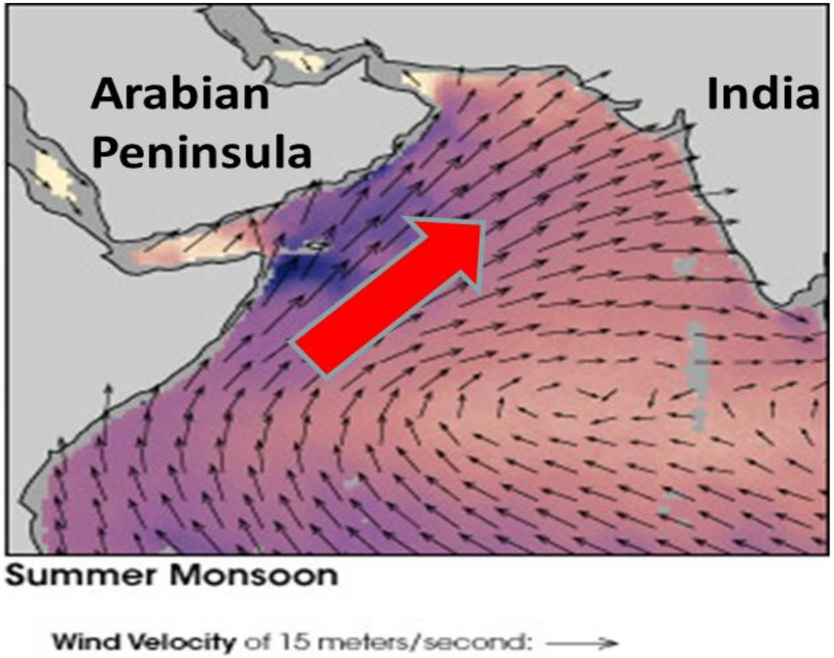
In the southern region, high number of SDS occurs compared to the northern region throughout 14 years.

High values of monthly dust events shift to summer when we move southward in the Middle East.

Monsoon Wind Cycle over Arabian Sea

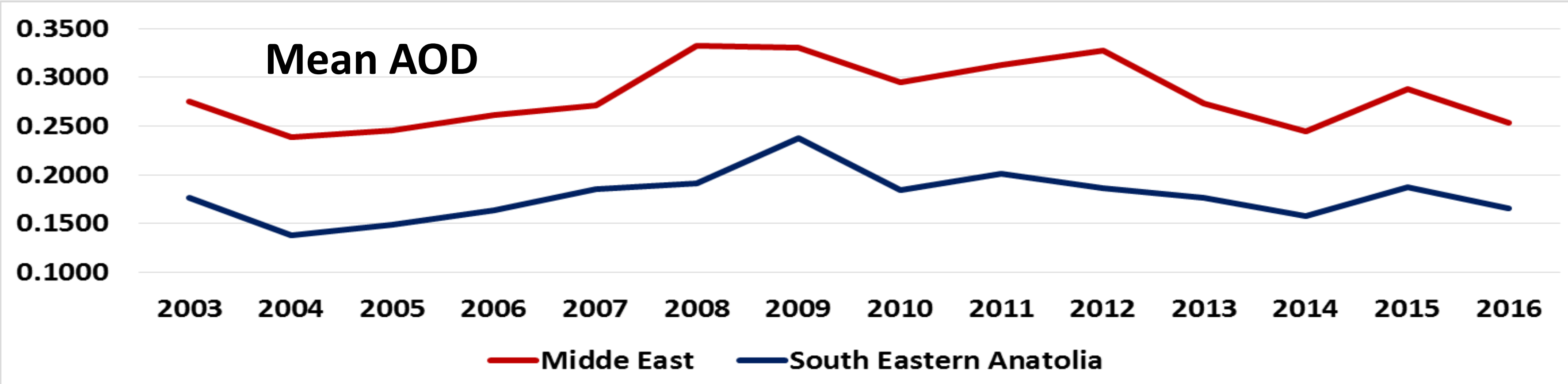
The aerosol events generally occurs in spring over northern parts of ME, while they occurs in summer over southern part. The monsoon system can cause that seasonal aerosol events.

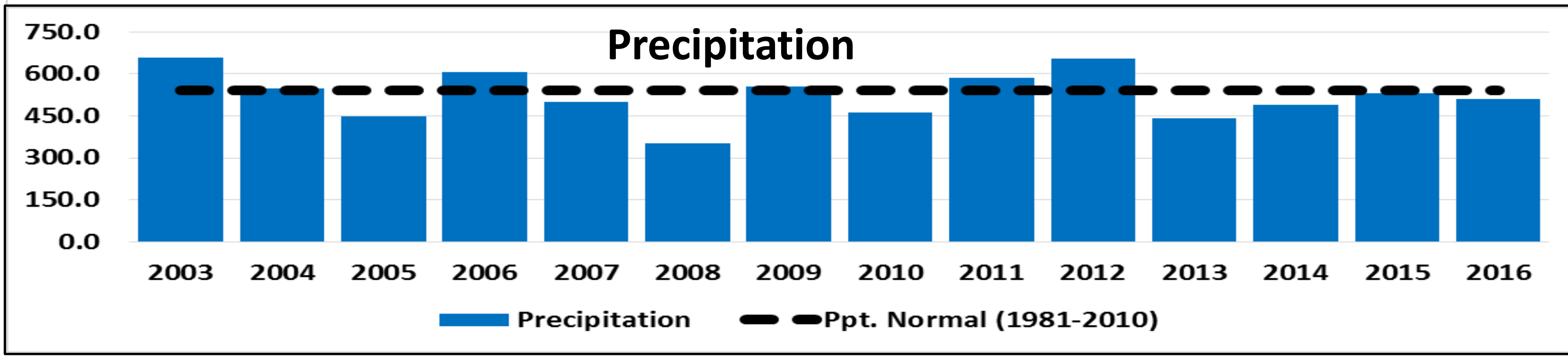


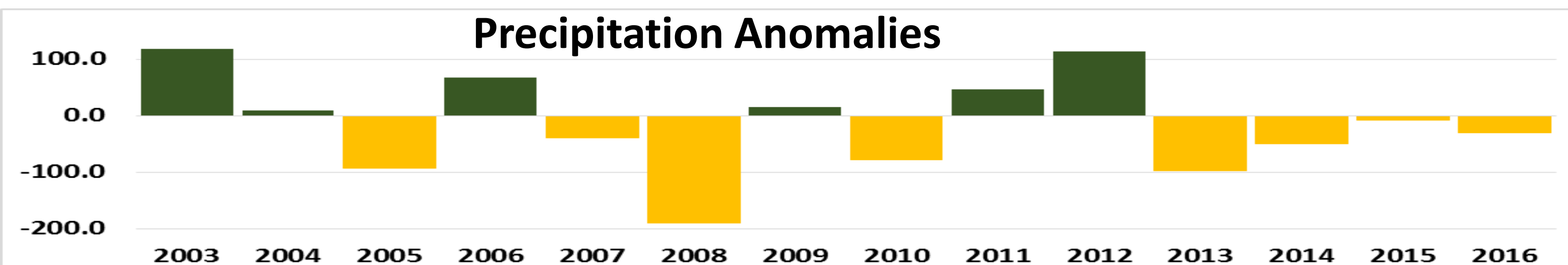


While the monsoon winds blow from the northeast to the southwest in winter, the strong winds blow from the southwest to the northeast in summer times. These strong winds can lift dusts from Arabian Deserts.

AOD & Precipitation Analysis







Result and Discussions

In general, the AOD and AE parameters can be used to differentiate between coarse and fine particles of aerosols. Mean AOD of the period 2003-2016 illustrates high AOD values reaching up to 0.5 over east of Saudi Arabia, Kuwait, Bahrain, Qatar, Iraq and Persian Gulf.

Low AE values are observed over Saudi Arabia, Iraq, Syria and Persian Gulf. Those areas with low AE and high AOD point out dust storms.

Moving southward along 20-38N latitudes, there is an increase in AOD values, accompanied by a decrease in AE values (coarse particles) in the same direction. It concludes that throughout 14 years, more strong and frequent dust storms are observed in the Southern Middle East which also shows different seasonal SDS characteristics.

To sum up, for the last years (2013-2016), annual mean AOD and the number of SDS are comparable lower than the other periods while the values are the highest between 2008 and 2012.