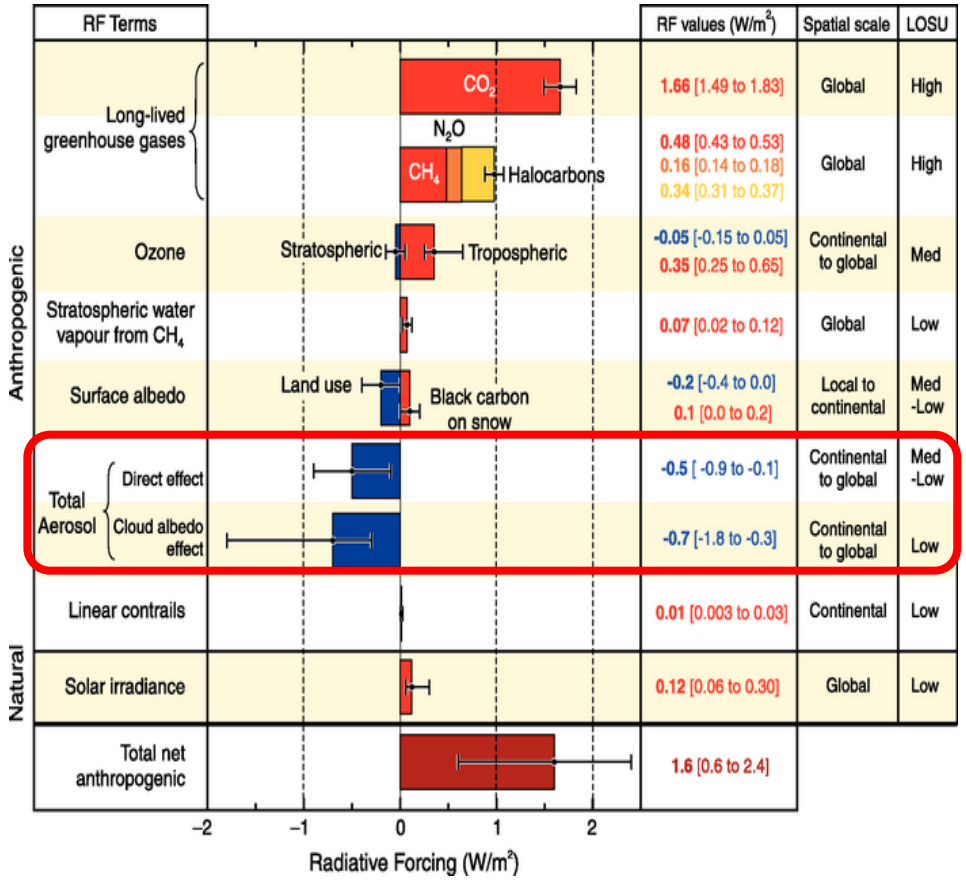
Long-term changes in aerosol loading and observed impacts on radiative budget over Middle East

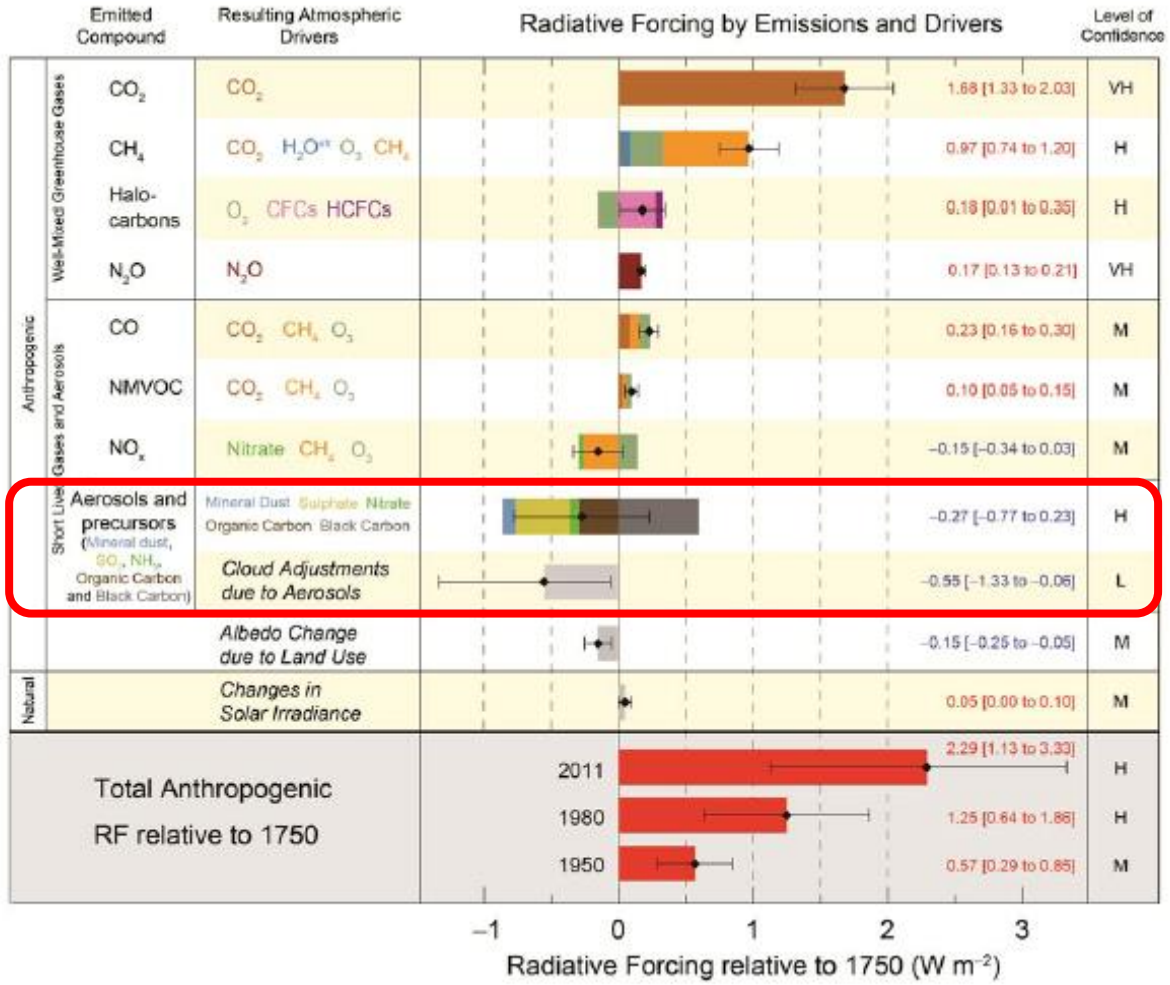
B. Dayanandan[1], Piyushkumar N. Patel[2,3], Pravash Tiwari[4], Issa Al-Amri[5], Smitha T.T[1], Humaid Al Badi[7], Khamis Al-Riyami[8]

[1]Department of Mathematical and Physical Sciences, College of Arts and Science, University of Nizwa, Oman
[2]NASA Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA
[3]Universities Space Research Association, Columbia, MD, USA,
[4]House no. 71, Sukubahal Galli, Thamel, Kathmandu, Nepal
[5]Department of Biological Sciences and Chemistry, College of Arts and Science, University of Nizwa, Oman
[6]Oman Meteorological Department of Muscat International Airport, Oman
[7]Natural and medical Sciences Research Centre, University of Nizwa, Oman

Background and Motivation



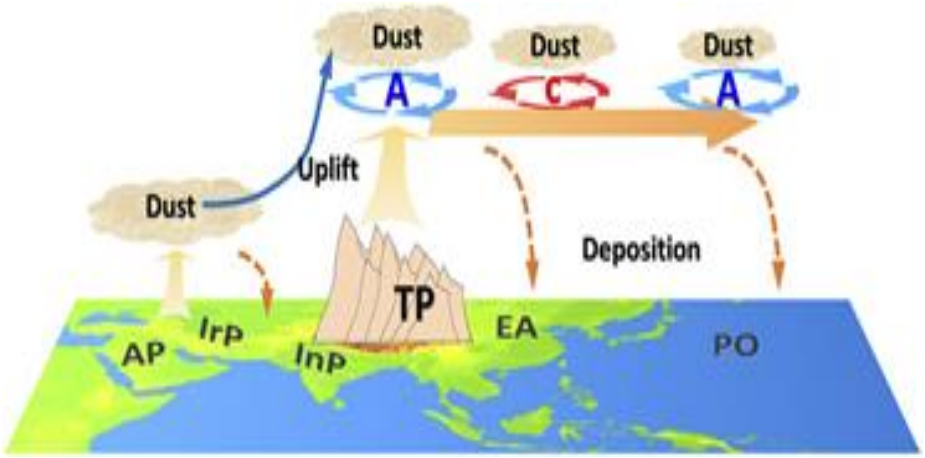
IPCC, AR4, (2007)



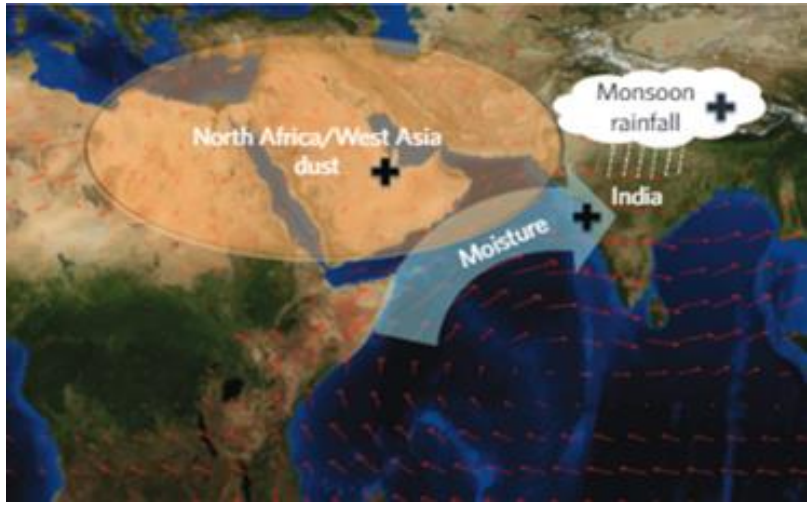
IPCC, AR5, (2013)

Middle East – Aerosol and Air pollution Overview

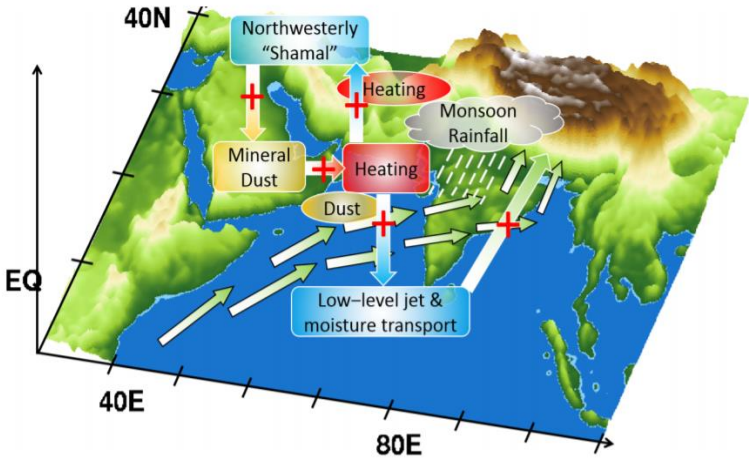
- The Middle East (ME) and the adjacent Mediterranean area have been identified as the most ***important hotspot for climate change***.
- Located in the ***center of the northern subtropical dust belt***, the Arabian Desert is the ***third-largest (after the Sahara and the East Asian deserts) region of dust generation***, and this dust plays an important role in regional climate control
- The Natural ***dust aerosol is very well supplemented with local anthropogenic emissions***
- The ME aerosols have regional as well as global influence



Xu et al., (2018)



Vinoj et al., (2014)



Jin et al., (2015)

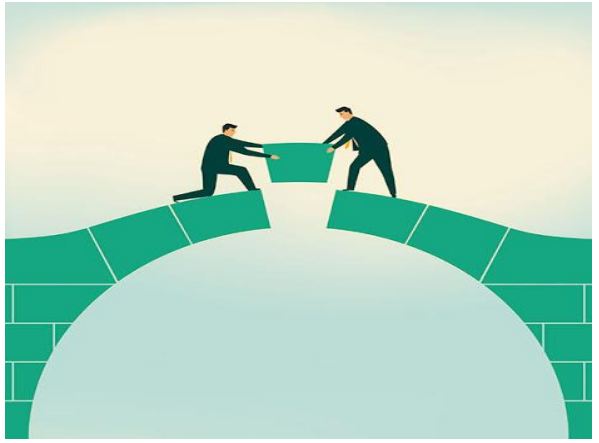
Study Goals

GAPS

- Till date studies are mostly limited to either site or country specific, and exploring dust storm anatomy
- Comprehensive investigation utilizing combination of different satellites and ground data is still lacking for the entire ME
- Availability of very limited aerosol studies particularly focused on climate perspective over the Middle East.

Study Goals

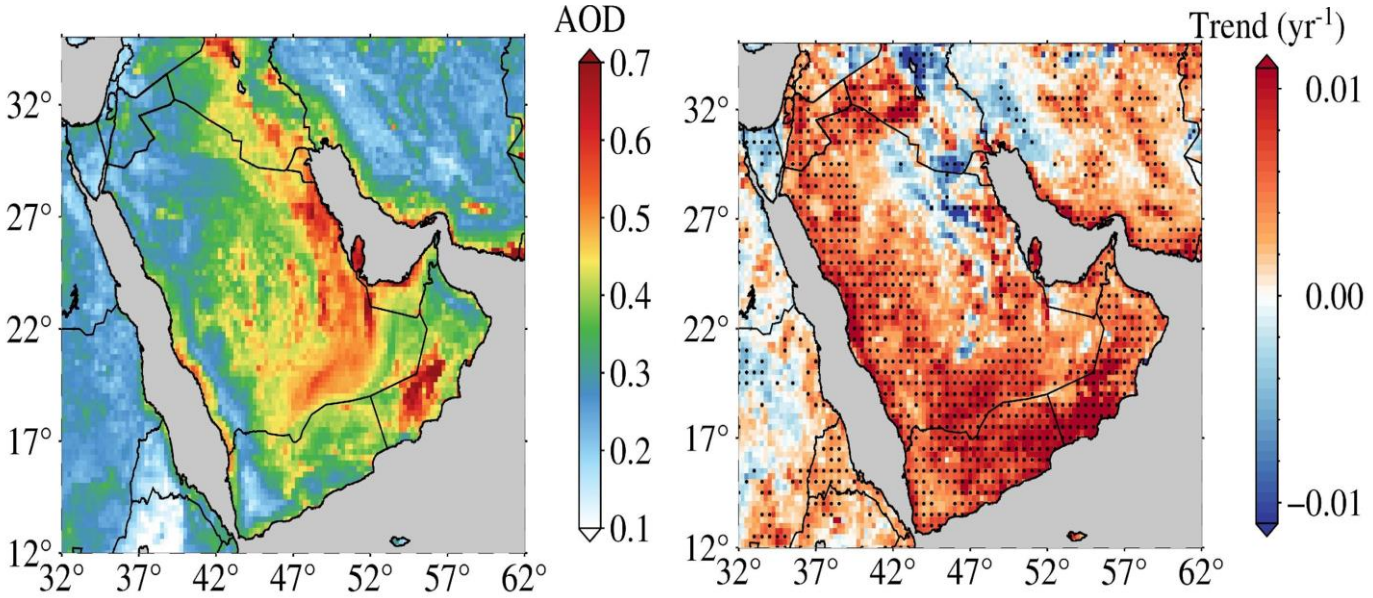
- A long term aerosol optical depth and aerosol type trend over the ME in the span of 14 years (2005-2018).
- Long term variation in radiative fluxes (surface and atmosphere) and heating rate over the region.
- Explore the interrelation between variation in aerosol optical depth, aerosol type and resultant radiative forcing.

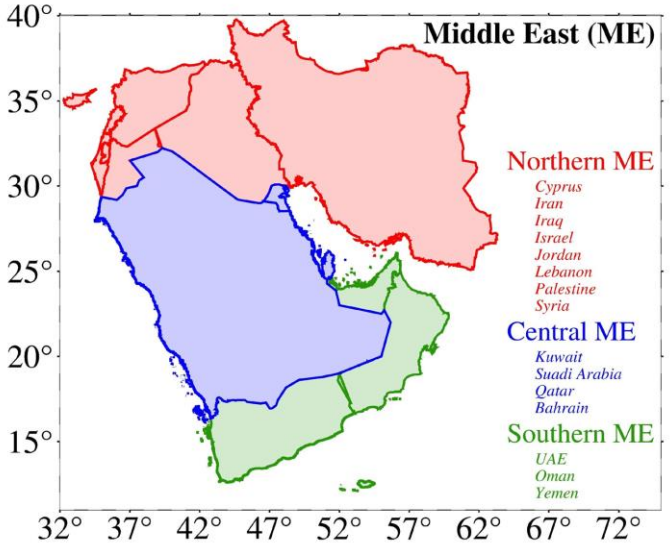


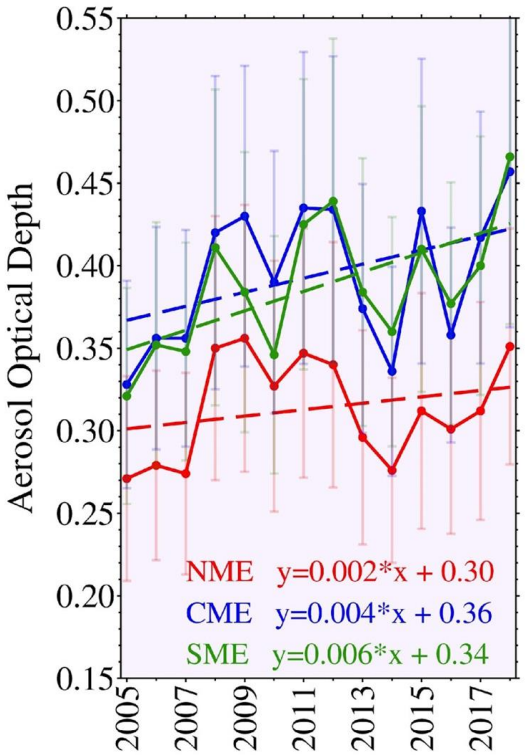
Data and Method

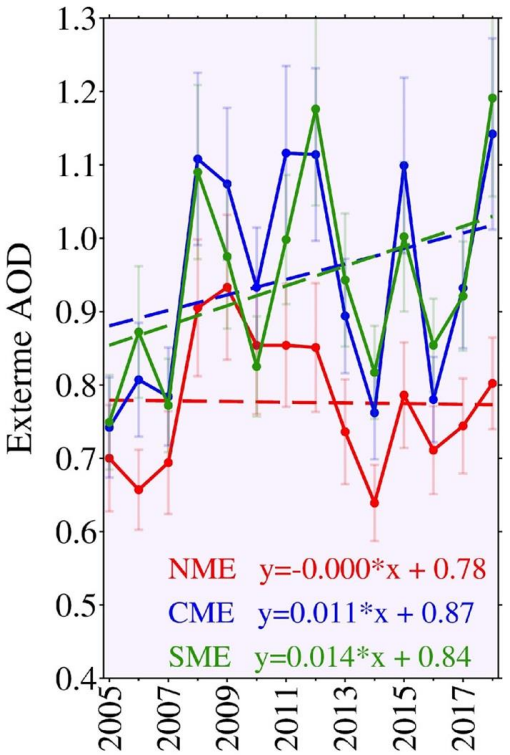
Data Source	Parameters	Resolution	Data Used
Satellite Observations			
MODIS	**Aerosol optical Depth (AOD)**	10 km x 10 km	2005-2019
CERES	**Top-of-the-atmosphere (TOA) radiative flux Surface SW flux**	20 km x 20 km	2005-2019
CALIPSO	**Vertical profile of aerosol extinction coefficients and aerosol types**	5km horizontal 30 m vertical	2006-2019
Ground-based Measurements			
AERONET	**aerosol optical depth**	15 min. for direct & 30 min. for almucantar measurements	Several station over ME

MODIS AOD over ME



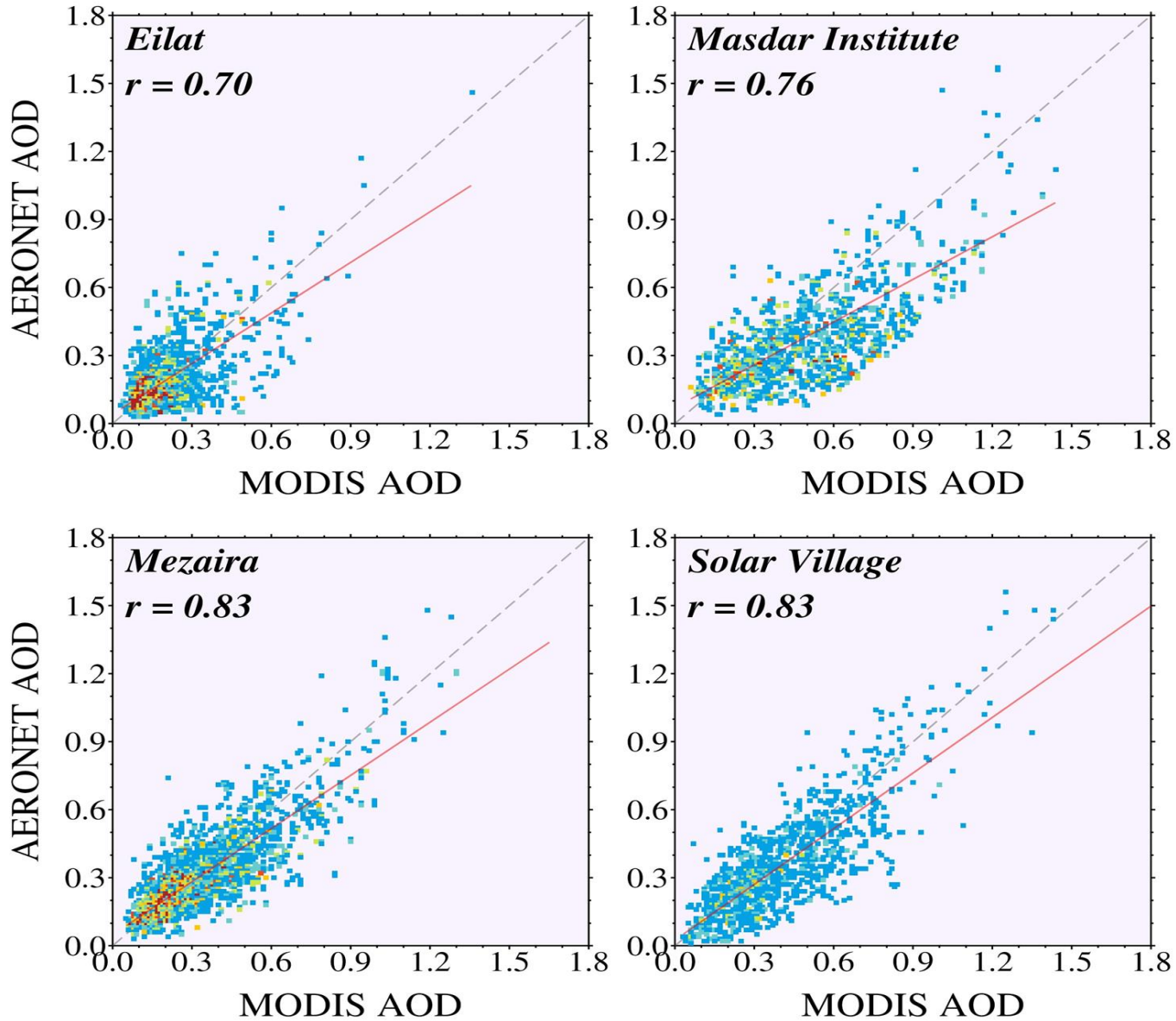




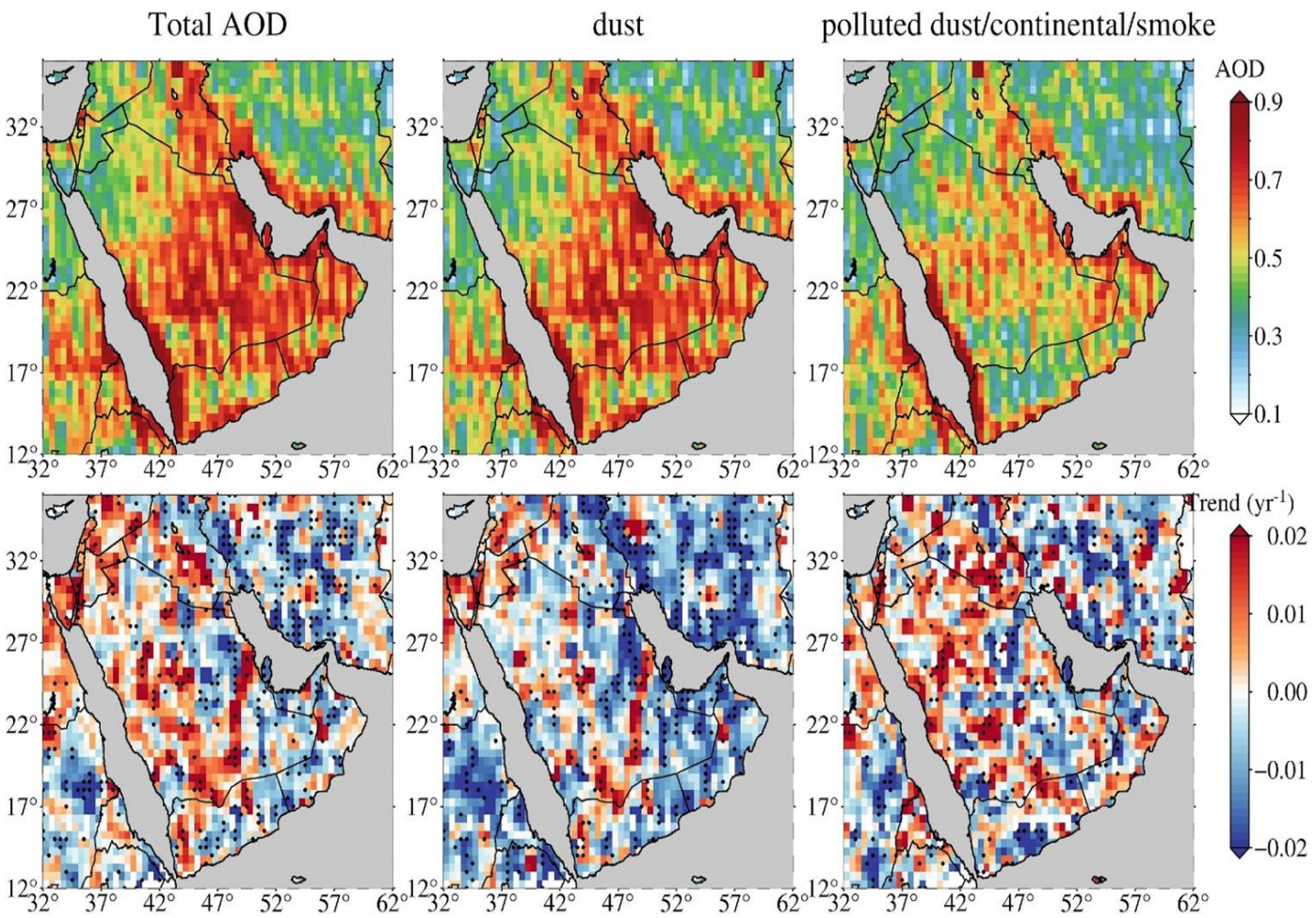


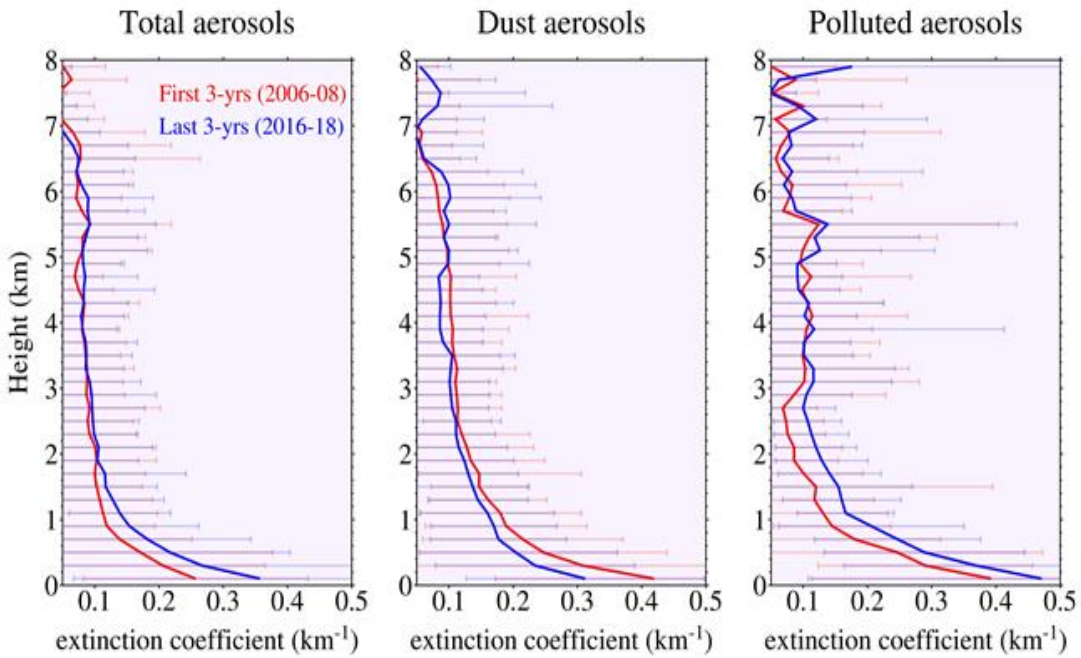
Region	AOD	Extreme AOD
NME	10%	-0.1%
CME	15%	17%
SME	24%	25%

MODIS AOD Vs. AERONET AOD



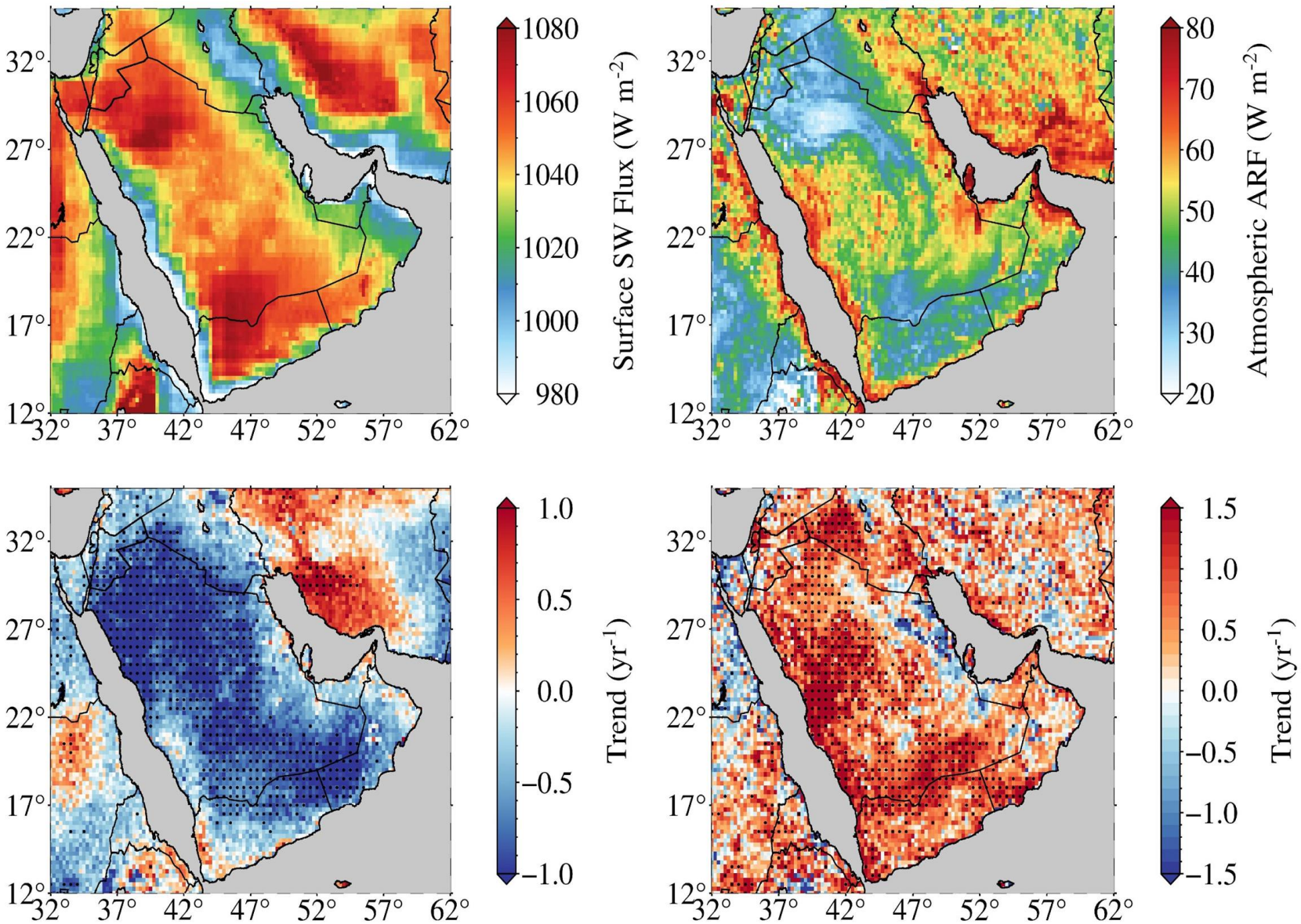
CALIPSO Extinction Profile and AOD



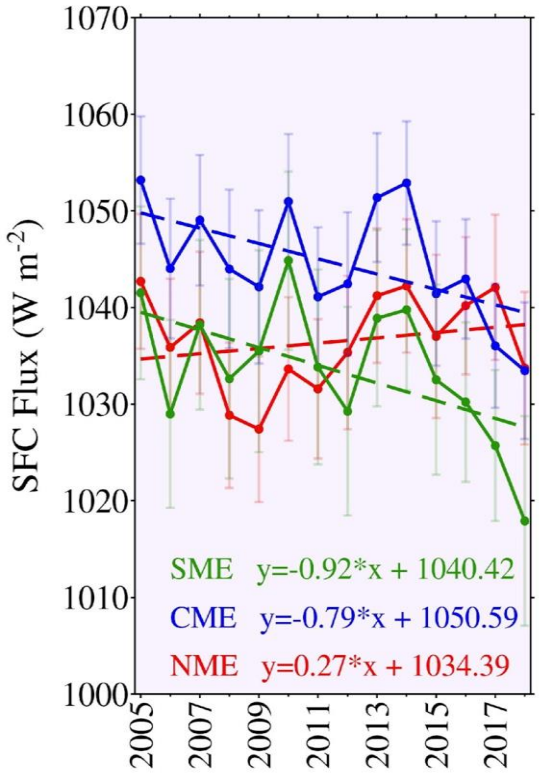


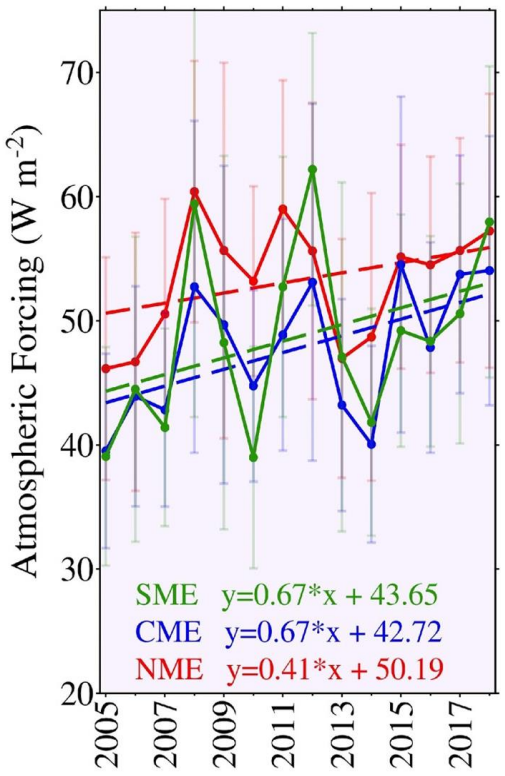
Aerosols	Relative percentage difference
Total aerosols	11%
Dust	-9%
Polluted	20%

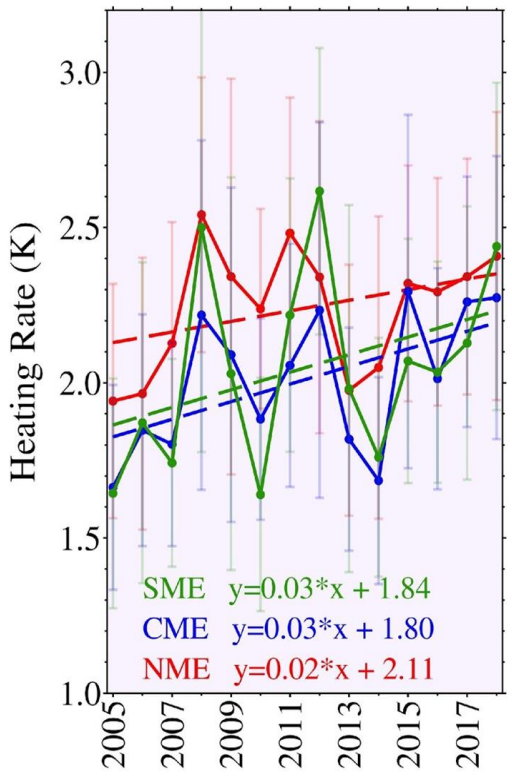
Surface Flux and Atmospheric Forcing



Surface Flux, Atmospheric Forcing and Heating Rate Trend







Region	Surface cooling	Atmospheric warming	Heating Rate
NME	1%	11%	13%
CME	4%	21%	23%
SME	5%	21%	23%

Conclusion

✔Long-term satellite observations reveal an ***overall increase in AOD and extreme AOD trends*** over the Middle East (ME). The regional analysis shows the highest increase in AOD trend over Southern ME (24%) followed by Central ME (15%) and Northern ME (10%). The validation of MODIS AOD showed good agreement against AERONET AOD, with ~70% of the retrievals falling within the expected error and ***high correlation coefficient (r > 0.7)***.

✔ CALIPSO derived AOD agrees well with MODIS AOD over most of ME, with ***an overall increasing pattern***. This also reveals a ***declining trend of dust aerosols and an increasing trend of polluted aerosols*** (polluted dust/polluted continental/smoke) over ME. The vertically-resolved extinction profiles between first (2006-08) and last three years (2016-18) reveal a similar findings.

✔Long-term increase in aerosol loading over ME ***enhances the surface cooling (~ -0.7 W m^{-2} per year) and atmospheric warming (~ 0.55 W m^{-2} per year)*** that further ***increase the heating rate by ~0.03 K per year***. The regional analysis reveals that aerosol-induced perturbation in regional radiative budget is more towards Southern ME than Northern ME.

✔Overall, the outcomes of the study show the long-term rise in aerosols over ME, and related conducive regional energy budget, are concerning and in turn provide an opportunity to strengthen mitigation action towards air quality and health assessment. This further provides an critical input for the regional and global climate models.

Thank You