Severe Dust Storms Over The Arabian Peninsula: Observation and Modeling

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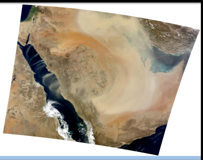


Dust aerosols and dust storms have tremendous effects on human health and many of human activities (site construction, agriculture, civil aviation, etc.) . Also atmospheric dust plays a major role in the Earth climate system by its interaction with radiation and clouds. Severe dust storms are considered to be the severest phenomena in the Arabian Peninsula, since they are occurring all year round with maximum activity and frequency in Summer. The Regional Climate Model (RegCM4) has been used to simulate severe dust storms events over the Arabian Peninsula from 1999 to 2012. This long period simulation shows typical patterns and dynamical features of dust storm activities and reveals different climatic zones for dust storm occurrence. The Aerosol Optical Depth (AOD) from the model outputs have been compared against ground--based observations of three AERONET stations (i.e., Kuwait, UAE-Mezaira and Solar-Village) and daily space--based observations of MISR, Deepblue (MODIS) and OMI. Also, the Top of Atmosphere radiative forcing and the Bottom of Atmosphere radiative forcing for short wave radiation have been analyzed and compared to the model's output. This long term analysis shows that, the Arabian Peninsula cab be divided into three climate zones, which represent different dust seasons. The second part of this study shows the synoptic feature of two severe dust storms at winter and summer, that could be generalized to other dust storm occurrence.

Methodology

Observation data set

1-Deep-blue satellite

2-OMI satellite

3-MISR satellite

4-AERONET

Model setup

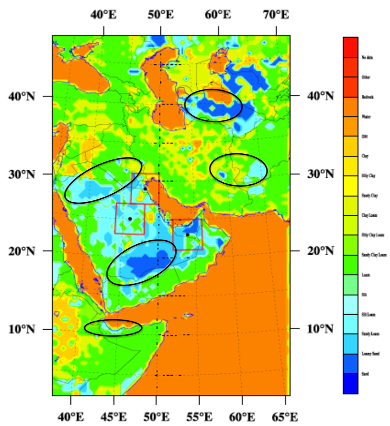
RegCM4 was run for 14 years (1999-2012) at a 50 km resolution, using the BATS land surface model, the University of Washington boundary layer scheme and the CCM3 radiation scheme. In this study, the dust aerosol is considered to be radiatively active.

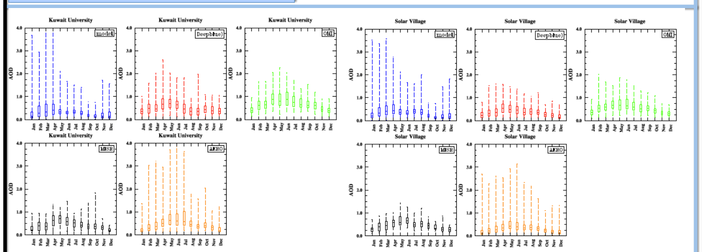
Statistics

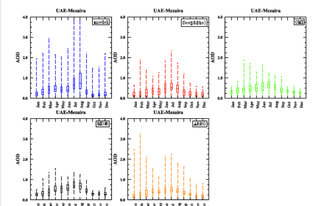
We have chosen three AERONET stations, namely, Kuwait University, Solar Village and UAE-Mezaira. These stations have the longest time records. All statistics are area averaged around the stations as indicated by the red boxes.

-The box-plots represent the (absolute minimum, the 25 %, 50 %, and 75 percentiles and the absolute maximum)

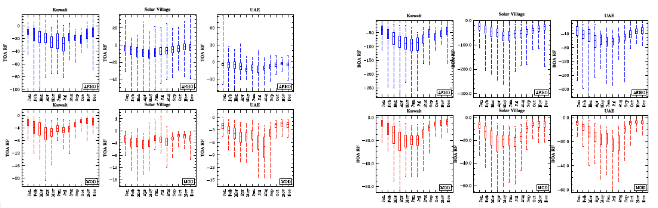
The oval shapes locate the area of intense dust sources over the model domain region, which are associated with "sand" soil texture type. The southern region is the El Robe El Khali desert, the north region is the El Nofod desert and the Eastern region is the Iran-Pakistan-Afganisatn desert.







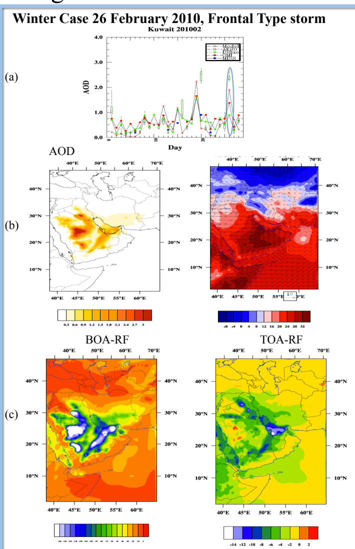
The comparison between model output and the available observations shows that, there are three climate zones for dust storm occurence. The Northern zone (represented by Kuwait), the Central zone (represented by Solar Village) and Southern zone (represented by UAE-Mezaira).
The dusty season in the Northern zone is mainly in MAY-JULY
The dusty season in the Central zone is mainly APRIL-JULY
The dusty season in the Southern zone is mainly in MARCH-AUGUST.
The Northern and the Central zones are driven by northerly wind (Shamal) which is active in summer season and associated with the Indian monsoon depression.
The Southern zone is affected by southerly wind, which developed when the Red Sea Trough extended inside the Peninsula in late spring. The strong southerly wind is caused by the Somali low level jet in summer.



The AERONET Radiative forcing is one inverse products of the AERONET measurements. The calculation corresponds to the measurements at high zenith angle (55-70) degrees (i.e., near sunset), which has proven to yield the most accurate measurements.

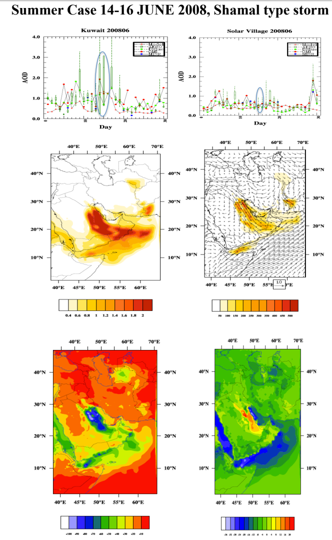
The Bottom of the Atmosphere radiative forcing (BOA-RF) shows differences in the magnitude and timing of the dusty season.
The Northern zone (Kuwait station) shows the strongest BOA-RF up to - 120 W/m^2 in MAY-JULY.
-The model underestimates the surface radiative forcing by a factor of 4.
-The Top of Atmosphere radiative forcing (TOA-RF) shows negative values, which reflects the scattering nature of the dust aerosol.
The model underestimates the value of TOA-RF by a factor of 4.

Winter Case 26 February 2010, Frontal Type storm



Most dust storms in winter are triggered by developed frontal systems, whenever they overpass a dust source region they uplift dust into the atmosphere. These kind of dust storms are called Frontal Dust Storm.
On 26th February 2010 an intense dust storm developed in the Northwest region of the Arabian Peninsula. This storm developed during the movement of a cold trough over dust source region.
(a) Shows the comparison between satellite data, AERONET, and the model; the model shows good agreement within the uncertainty of the observations.
(b) Shows the spatial distribution of AOD over the region and the corresponding surface condition for dust uplifting. The strong cold advection in the north-west that triggered the northern part of the storm, however the south-west wind (Red Sea trough) is responsible for the southern part of the storm as in shown in AOD Figure.
(c) Shows the strong cooling effects caused by the dust storm, The negative RF reaches up to -160 W/m^2 The TOA-RF also shows a negative signal. The cooling effect of the dust cloud is more pronounced when it is concentrated in upper layers above the boundary layer height.

Summer Case 14-16 JUNE 2008, Shamal type storm



Most dust storms in summer are a result of strong northerly to north-westerly winds called (Shamal wind). The Summer Shamal is part of the summer Indian monsoon depression that extends to the Arabian Peninsula. Between the 14th and 16th of June 2008, a strong Shamal wind resulted in an intense sand storm in the eastern part of the Arabian Peninsula. The Model underestimated the AOD values in Kuwait and Solar-Village. The strength of the Shamal wind pushed the dust to the Indian ocean.
The Surface RF shows strong negative values up to -90 W/m^2 which is less than for the winter case.
The TOA RF shows negative values over the ocean and positive values over the land, due to the strong land surface albedo in summer

Conclusions

Comparing satellite data, AERONET and model output for AOD and radiative forcing reveals a different dust storm climatology over the Arabian Peninsula.
There are discrepancies between satellite data, AERONET and model results in the seasonal cycle. RegCM4 shows one month lag of the onset of the dusty season in Kuwait and Solar-Village but has better performance for UAE-Mezaira site.
Severe dust storms that cover most of the Arabian Peninsula are rare events and are the result of large scale synoptic situations. In winter the coupling between the mid-latitude cold front and the extension of the Red Sea trough uplifts dusts from many dust sources in a short time frame, which can result in large scale dust storms.
In summer, the northerly wind (Shamal) blows parallel to the Persian Gulf and overpasses major dust sources. Thus, it uplifts and transport dust for a long distance reaching as far as the Indian Ocean.

Future Work

1-Dust storm climatic feedback, 2-The interannual variability of dust storm

References

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