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RESEARCH ARTICLE

Simulation of sandstorm over United Arab Emirates using Weather Research and Forecasting modeling system

Abdulhamid Ali Alraeesi

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Abstract

The aim of this study is to improve the dust storm weather forecast using modeling system, with one of the most recent techniques that is WRF model, The Weather Research and Forecasting Model is a numerical weather prediction system designed to serve both atmospheric research and operational forecasting needs. In this study I use (ARW) Advanced Research WRF model, for present case study the result was very much acceptable when comparing with the actual observation data.

Introduction

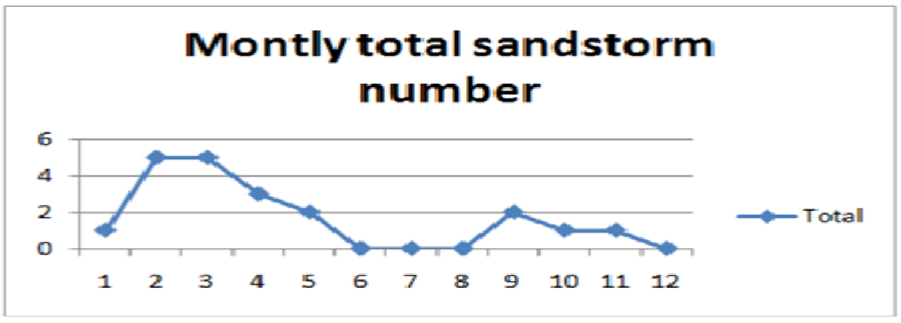
Sand storm and dust storm are not only meteorological phenomenon, Dust storms may cause a variety of problems. One of the major problem is reducing the visibility that limits various activities (Morales, 1979).

The Arabian sea region is one of the dustiest area in the world (Kutiel and Furman,2003) and has been listed as one of five major dust producing area (Idso, 1976), while (Goudie, 1983) added that dust storms are frequent in the area. Dust storm and sand stormtends to poor visibility and strong gusty winds are a danger to aircraft landing and taking off, this can lead to diverted flights, delayed departures and restricted airport operational problems. Other effects include the sourcing of aircraft surface and damage to engines as well as hampering ground operations.

Sandstorm is an ensemble of particles of dust or sand lifted to great heights by strong turbulent winds. Horizontal visibility is reduced to below 1000 meter.

2. Area of Topography and locations

In this research I will focus on Abu Dhabi airport in UAE, the UAE is situated on the Arabian Peninsula between Oman and Saudi Arabia and bordering the gulf of Oman and the Arabian Gulf. The area of UAE is 77700 square kilometer, the land boundaries total 867 kilometer. The length of coastline is 1318 kilometer (Library – 2007). The United Arab Emirates has two distinct land elevation zones. The larger sandy desert zone covers over ninety percent of the country's surface area (UAE climate, 1996).

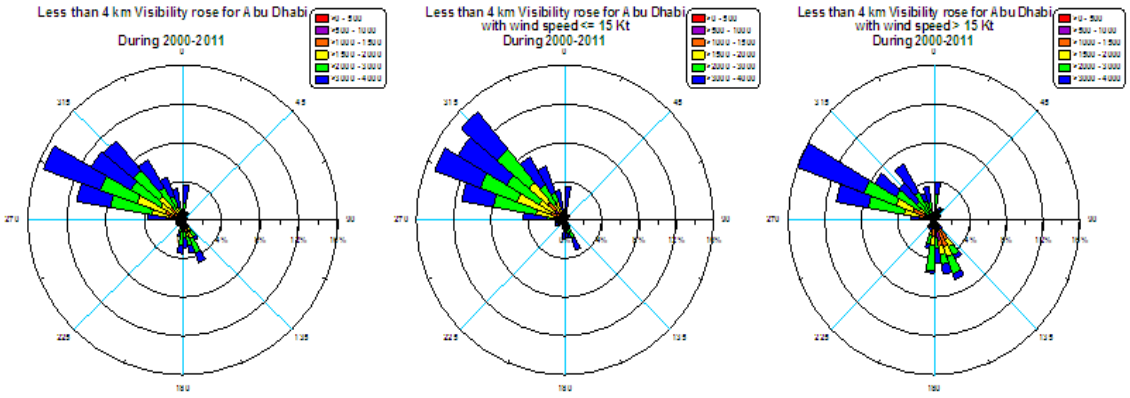


(Figure1): frequency of sandstorm from 2000 till 2010

Most sand storm occur in winter month specially February and March, Abu Dhabi for the 11 years between (2000-2010) sand storm occured 20 times at an average of two times in a year (see figure1).

3- Advection and local dust

The word advection means coming from another place and the wind at the station of reporting is less than 15 knots.In below all graph we talk about wind rose with wind speed less than or equal 15 kt and more than 15kt, less than or equal we called advection dust and more than 15 kt we called local dust.



(Figure 2): Visibility Rose for Abu Dhabi Int. Airport Station with all wind speed, with wind speed <= 15 kt , and with WS > 15 kt

From left first graph for Abu Dhabi airport station we can see most dust from northwest or west to north direction big open area and construction area lead dust to rise. South to southeasterly winds can also be a source for dust in Abu Dhabi airport. The second graph we can see the advection dust, 90% coming from west to north and 10 % of dust coming from south to southeast. For local dust in Abu Dhabi airport and wind speed more than 15kt there are two common directions from (280 till 360) direction and (130 till 200) direction.

4- Aerosol optical thickness measurements (AOT)

Aerosol optical thickness or Aerosol Optical Depth (τ, tau) is the degree to which aerosols stop the transmission of light by absorption or scattering of beam or light.

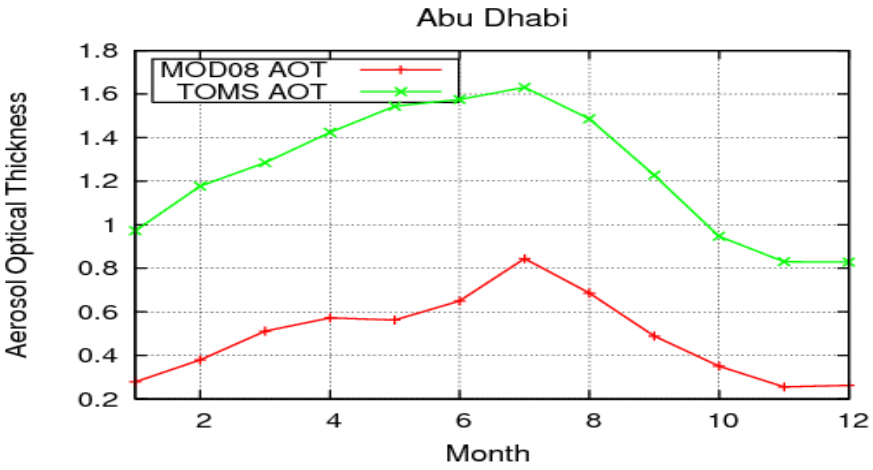
The aerosol optical depth or optical thickness is defined as the integrated extinction coefficient over a vertical column of unit cross section.

The atmosphere is made up of small molecules of gas and small suspended particles called aerosols. Aerosols can be solid or liquid particles ranging in size from a fraction of micrometer to a few hundred micrometers (Ulrich poschl, 2005). They originate from a variety of natural and anthropogenic sources.

Aerosols affect our weather and climate because they affect the amount of sunlight reaching earth's surface, the aerosol optical depth (AOD) is an index measuring the radiation attenuation during its passage through the atmosphere (Mian chin, Ralph a. khan, Stephen E. Schwartz, 2009). The attenuation is due to the presence of suspended particles. AOD and "turbidity" are essentially synonymous quantities, both being logarithmic indices of atmospheric optical attenuation to vertical beam.

Aerosol optical depth thickness is a calculate of the extent which aerosols affect the channel pr way of sunlight through the atmosphere. As the optical thickness at a particular measurement of aerosol optical thickness at more than one wavelength can present important information about the concentration, size distribution, and variability of aerosols in the atmosphere.

The data for Aerosol optical depth taken from Giovanni(disc.sci.gsfc.nasa.gov/giovanni) and from Toms (http:// toms.gsfc.nasa.gov).



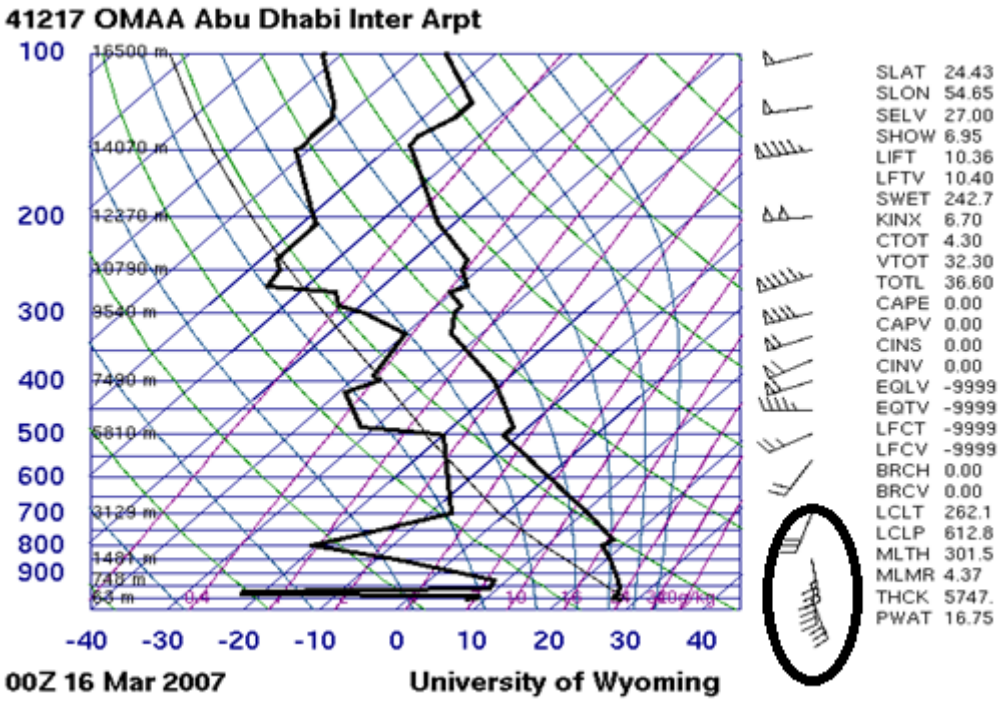
(Figure 3): Abu Dhabi Monthly AOT from TOMS and MOD08

Figure 3 illustrates the monthly AOT from TOMS and MOD08 for Abu Dhabi station the interval between 2005 till 2013. The green line trend us the heights AOT will be during the summer month especially during the July month and will be above to (1.5).

The red line Giovanni MOD08 trend us the heights AOT will be during summer month (July) as the maximum peak, and around 1, for winter month will be less than (0.4).

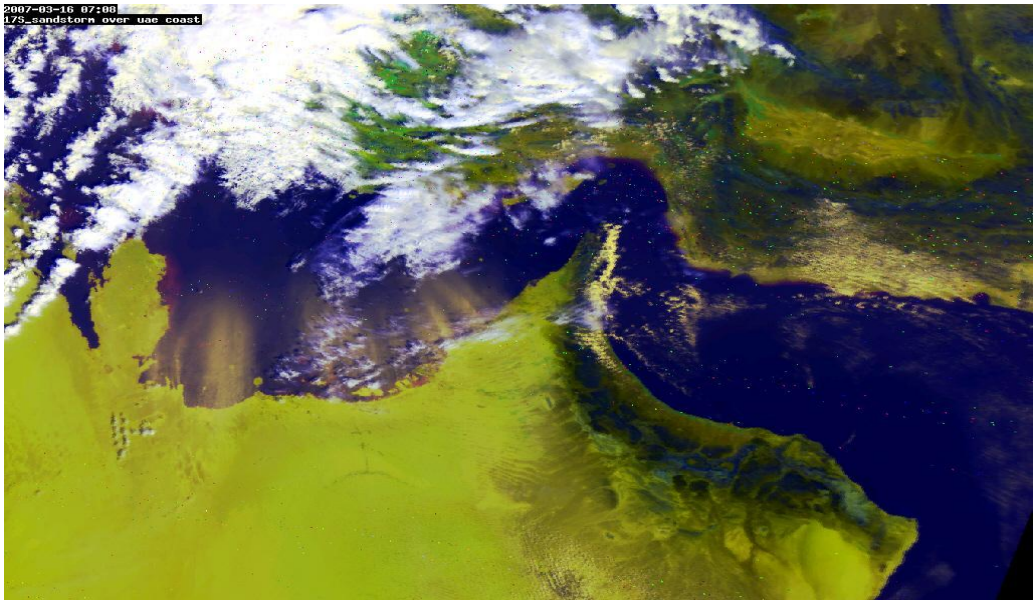
From both Giovanni and TOMS the summer month will the peak of aerosols optical depth, the reason behind that the summer shamal lead to raise the dust over Abu Dhabi and less rain or precipitation in summer month leads the sand to move easily and causing the dusty conditions.

5- Case of sandstorm over Abu Dhabi airport on 16 March 2007



(Figure 4): Abu Dhabi ascent valid from 00z 16 mar 2007

From Abu dhabi ascent showing very strong southeasterly surface wind (see the black circle) and good indication for strong winds near the surface, the ascent helps us to make our daily weather forecast.



(Figure 5): HRPT image showing dust in yellow color over the Arabian see

High Resolution Picture Transmission (HRPT) Image includes all chanel image, from figure 5 we can see yellow dust over the Arabian sea during the frontal passage on 16th of March 2007.

In this example I want to show and prove how the model helps us to forecast any severe weather like sandstorm, in my case I used WRF-ARW model more accurately and yielded good result. Sandstorm occured between 05z till 09z.

Temperature																							
Time	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Climate	26	26	25	24	24	26	28	29	31	32	33	33	33	33	33	32	31	30	29	29	29	23	22	22
WRF	26	24	23	23	24	25	26	28	30	31	32	33	33	33	31	30	29	28	28	28	27	23	22	21
Average for day	21	21	20	20	21	23	26	29	30	30	31	30	30	29	27	26	25	24	23	23	22	21	21	21

(Table 1): Temperature of case study

From table 1 the temperature from the actual report and the model the maximum differencewas 2 degree and occurred 8 times, one degree differenceoccurred for 9 times and same temperature between models and actual occurred for 7 times, one to two degree differences are acceptable from the model but it is very difficult to get the same temperature for 24 hours.

Humidity																								
Time	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Climate	34	34	36	47	53	51	42	37	29	19	29	28	28	28	28	29	29	31	33	35	35	83	83	78
WRF		48	52	55	54	54	50	44	38	33	32	28	24	22	23	27	30	31	32	34	37	77	88	92
Average for day	64	63	65	66	61	53	42	33	29	30	31	35	32	38	44	48	52	55	57	57	57	62	63	64

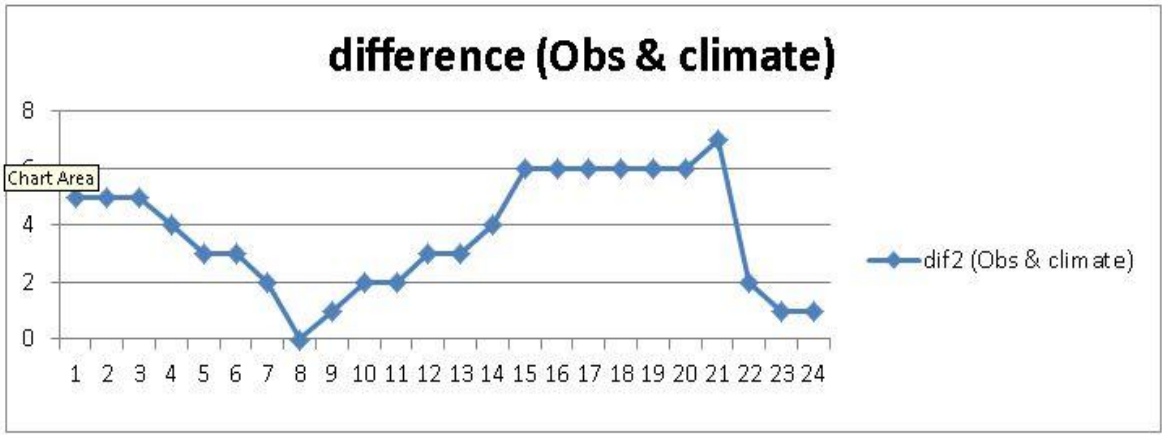
(Table 2): Humidity of case study

Table 2 showsthat the humidity is mostly different between the model and actual or climate data which is less than 10 percent in sand storm period, this result is acceptable from the model.

Wind Speed and Direction																								
Time	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Climate Speed	15	15	16	16	21	25	29	25	23	21	20	20	20	17	17	10	7	6	9	9	13	16	16	12
Climate direction	170	170	170	160	170	160	170	170	190	190	190	190	200	180	180	190	200	190	180	170	250	310	310	320
WRF Speed	20	15	15	20	25	25	25	25	25	25	20	20	20	20	15	10	10	10	15	15	15	10	10	5
WRF direction	160	160	160	160	160	160	160	160	170	170	180	180	180	180	180	180	170	170	170	170	170	280	280	280

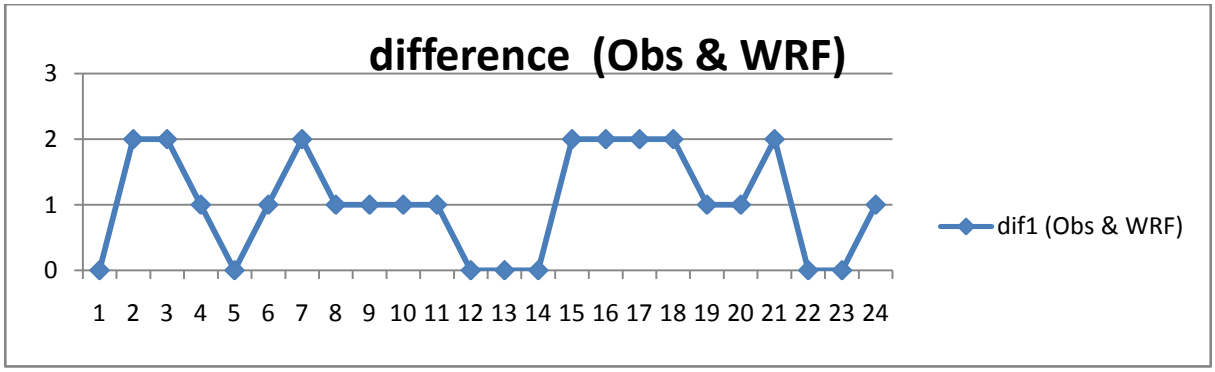
(Table 3): Wind speed and Direction of case study

Table 3 shows the actual wind speed which is reported at the station reaches 20 knots or more from 04z till 12z and WRF model give us 20 knots or more from 03z till 13z they are very close and cover the full period of strong wind, the wind direction for both actual and models are same between (160-180) degree this result show how the model and actual data are similar and how the model helps us to make good weather forecast.



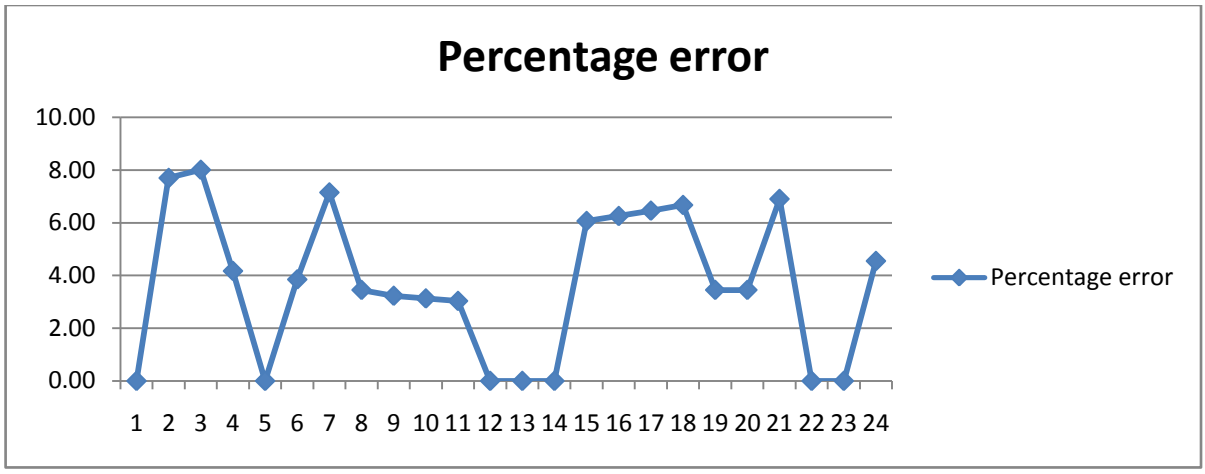
(Figure 6): Temperature difference between actual and climate

Figure 6 shows the difference between actual and climate temperature from (2000 to 2010) the maximum difference is around 7 degrees which is not acceptable as it is a very big difference.



(Figure 7): temperature difference between Actual and WRF model

Figure7 shows the difference between actual and WRF model temperatures, the maximum difference is around 2 degrees which is acceptable and can be used in preparing our daily weather forecast.Seven hours in day there is not much difference between actual and WRF model, this lead us to accept the model data.



(Figure 8): Temperature percentage error between actual and model results

Figure 8 shows the percentage error between actual and WRF temperature, the maximum percentage error is around 8 % which is acceptable.

6- Conclusion

1- Most sandstorms occur in winter months that is February and March in Abu Dhabi airport.
2- Most Advection dust around 85% comes from northwest direction and 15% from southeast, but for wind speed of 15 knots or more 60% comes from northwest and 40% from southeast direction.
3- The highest AOD over Abu Dhabi are in the month of July.
4- WRF model data is better than the average for temperature and humidity.
5- The highest percentage error is around 8 percent which is acceptable.

7. Reference

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