Fog Formation, Cause and Types Over the AbuDhabi International Airport, United Arab Emirates

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ABSTRACT

Fog is a meteorological event which has a significant impact on many human activities such as transportation, civil aviation, and military operations. UAE experiences many dense fog episodes over the course of a year which effect the visibility conditions strongly, especially during the winter months. In this research, we studied the fog events over Abu Dhabi International Airport (OMAA), which is located at the northeastern coast of UAE, using METAR (2012 to 2022) and ERA5 data. The number of fog days per year, the seasonal cycle, the diurnal cycle, and the duration of fog events were analyzed. Fog events are most frequent between September to March with a peak during December and January. Statistics of the fog events and the related atmospheric variables such as temperature, relative humidity, wind speed and direction during the fog episodes will be presented. Additional case studies that were conducted to understand and explain the reasons and types of the fog events over the region will also be displayed.

INTRODUCTION

In order to make fog, water vapor must first condense on condensation nuclei, which are always present in the outdoor air. As soon as the air's relative humidity rises even a tiny bit above saturation, something occurs. The nuclei in air that has been extensively polluted may grow large enough to cause fog at humidity levels of 95% or below. Radiation fog, advection fog, and evaporation fog are the three types of fog that are produced by cooling. In radiation fog, the Earth radiates heat away from the surface, which causes the air near the surface to cool and condense as fog. It needs a little wind of around 5 kt to form, but above 5 kt, the wind will totally blow out the fog. Warm wet air moving in a horizontal direction from the land meets the surface of the ocean to form advection fog, which cools and condenses. Evaporation fog develops when droplets from warm air fall into cold, stable air below, it occurs when chilly air passes over warm water. The water's surface may evaporate enough moisture to immediately saturate the air above it. In this study, we'll examine the occasions when fog forms over the United Arab Emirates, analyze how other factors affect that contribution, and identify the most common fog kind there. We have worked on data from Abu Dhabi International Airport.

Based on other studies conducted in the same region, we hypothesize that radiation fog is the most common type of fog over the UAE. Additionally, because of the lower surface temperature that results in temperature inversions and increased relative humidity throughout the winter, we anticipate seeing more fog episodes. It is necessary for there to be light breezes for the radiation fog to form and to prevent fog obstruction because if the wind speed is strong, the fog will dissipate.

STUDY AREA, DATA & METHODS

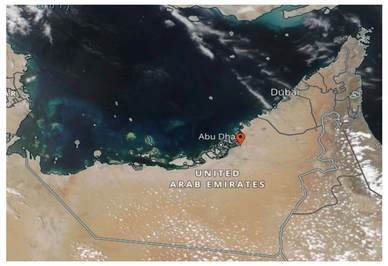

Fig. 1 Locations of the OMAA on UAE map Using NASA's World View

Station	Latitude	Longitude
Coordinates		
OMAA	24.4419° N	54.6501° E

Fig. 2 Coordinates of stations

The study area covers Abu Dhabi International Airport AUH, Dubai International Airport DXB, and Alain International Airport AAN. AUH has an elevation of 27 meters, DXB has e used METAR observations recorded over an 11-year period from 2012 to 2022 at the selected airports which are obtained from The NOAA National Centers for Environmental Information.
To classify fog by its type, we used the fog classification method used by Tardif and Rasmussen (2007), which defines fog into five different categories. For this study, we considered: Radiation Fog, Advection Fog, and Evaporation Fog. Radiation fog characteristics: (a) at night, there should be winds with speeds under 2.5m/s (5 knots).(b) There should be cooling an hour before the beginning of the fog with the lack of clouds. Advection fog should start as a "wall" of fog as it reaches the station, with a wind speed higher than 2.5m/s (5 knots), along with a sudden decrease of visibility or cloud ceiling decrease below 200m. For Evaporation fog, they should be an increase in temperature and an even more significant increase in dewpoint temperature, which leads to saturation during the first hour of sunrise
Moreover, we examined meteorological factors and their suitability for fog formation on three case studies of dense fog episodes observed on January 22–23, 2013, November 23, 2014, and December 3–5, 2016, using Wyoming Upper Air Sounding data for its a vertical profile of the atmosphere from these soundings. In addition, using the fifth major global reanalysis performed by the European Centre for Medium-Range Weather Forecasts (ECMWF) [ERA5; Climate Data Store (CDS) 2017], to display wind speed and direction on maps for the case study as well.

REFERENCE

Weston, M., Temimi, M., Burger, R., & Piketh, S. (2021). A Fog Climatology at Abu Dhabi International Airport. Journal of Applied Meteorology and Climatology, 60(2), 223-236.
Aldababseh, A., & Temimi, M. (2017). Analysis of the long-term variability of poor visibility events in the UAE and the link with climate dynamics. Atmosphere, 8(12), 242.
Mohan, T. S., Temimi, M., Ajayamohan, R. S., Nelli, N. R., Fonseca, R., Weston, M., & Valappil, V. (2020). On the investigation of the typology of fog events in an arid environment and the link with climate patterns. Monthly Weather Review, 148(8), 3181-3202.
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European Centre for Medium-Range Weather Forecasts (ECMWF) [ERA5; Climate Data Store (CDS) 2017].

There are more references that are cited in the supplementary material.

RESULTS

Fog Days

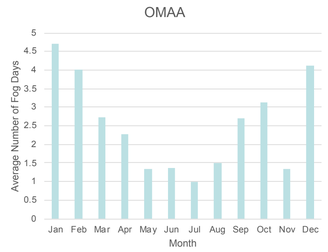

Fig. 3 Long Term Monthly Average Fog Days From 2012 to 2022 at OMAA

This chart shows the average number of fog days per month from 2012-2022 at Abu Dhabi International Airport. During winter, fog events were more frequent, peaking in January and December, moreover, fog events were less frequently seen during summer, with a minimum average of 1 fog days per month in July. The Diurnal Variation in these airports generally show that the fog events begin around 9-11PM Local Time (LT) and Dissipate around 9-10AM LT due to the solar heating. The Duration Variation of these fog events mostly lasted less than an hour to an hour, however, there are cases when fog events lasted over 9 hours, which during January and December

Atmospheric Variables

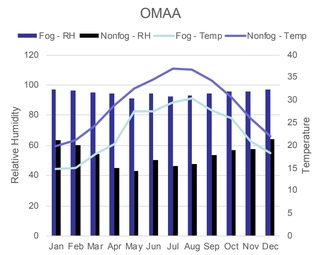

Fig. 4 Long Term Monthly Average Temperature and Relative Humidity for Fog Days And Non-Fog Days at OMAA

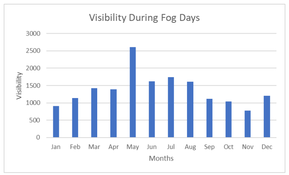

Fig. 5 Long Term Monthly Average Visibility During Fog Days at OMAA

Figure (4) explains that during the summer season (June – August) the temperatures during the non-fog days is usually more than 35 ̊C, and its relative humidity is lower than 50%, which are the conditions make it difficult for the fog to form. Whereas during the winter season (December – February) the temperatures during the fog days is usually less than 25 ̊C, and its relative humidity is closer than 90%. This correlated that when the temperature is below 25̊C and the relative humidity is above 90%, the magnitude of amount of fog increases, which confirms that fog events are more frequent during winter. The Visibility as shown in Figure (5) was affected by the fog events. In winter, the visibility deteriorates significantly due to the fog events reach under 800m. In summer, the visibility during the fog events is slightly higher, but is still around 1000m. The cases where the fog visibility was higher than 1000m, it was during BCFG reported in the METAR.

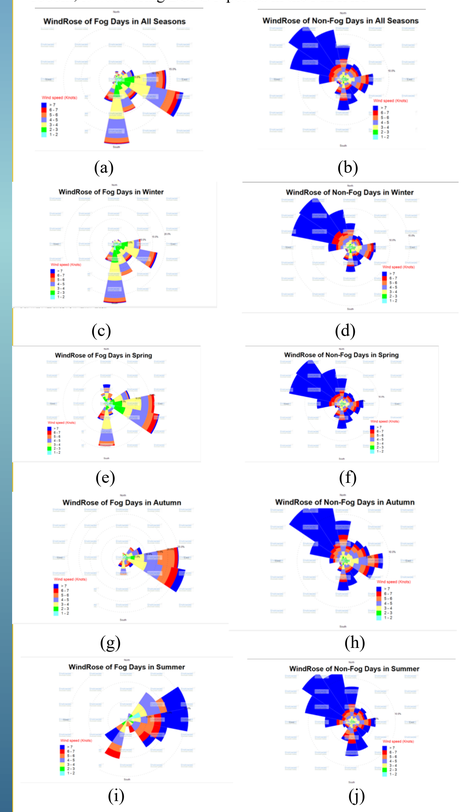

Fig. 6 The Variation of Wind Roses of Wind Speed and Wind Direction in Fog Days and Non-Fog Days at OMAA

The Figure (6) displays that the winds during the fog days are different than winds during normal non-fog days. The wind speed is around 5 knots in all stations during fog days, and they exceed 5 knots during non-fog days. The wind direction changes varies for ach station. In AUH, the general wind direction during fog days are south to south-easterly winds, whereas in non-fog days, the winds are north-westerlies.

FOG CASE STUDY

The Case Studies are performed based of a conceptual diagram illustrated by (Weston, Temimi ; 2021) that explains the effect of the radiative cooling that causes the sea breeze the transport the moisture to the land to weaken. Which results in surface inversion layer to form that can cause the dew point to be reached and fog forms.

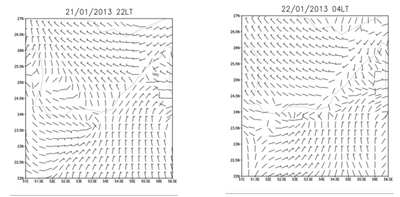

Fig. 6 Wind Speed and Direction Before and During the Occurrence of A Dense Fog Event

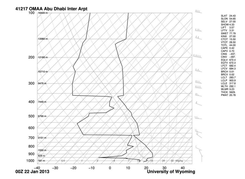

Fig. 7 Tephigram of 6 Hours Before the Fog Event

The day before the fog event (January 21st), calm northerly winds (3-5 kt) accompanied with haze, as it brings moisture from the gulf. The RH is increasing along the night, with the presence of haze. On the 22nd, the wind direction shifted to southeasterly after the incoming of moisture from the Gulf, and the visibility dropped to 50, haze developed to fog. Due to that, the RH has reached 100% with calm winds, temperature and dewpoint were 17. The temperature and dewpoint remained equal with high RH until 6:00 and dissipated afterwards. At 20:00, fog was formed again with southwesterly winds, with a minimum visibility of 100, which was in the last hour of the day. Fog lasted until the next day (January 23rd, 6:00), and it dissipated when the visibility exceeded 3000 (due to solar heating), with mist being present for about half an hour, and then it dissipated completely. A layer of warmer air may trap the cool air as it approaches the surface, preventing it from mixing with the surrounding air. Fog can develop within the inversion layer when the moisture in this trapped cool air, which is often from nearby water sources, becomes saturated.

CONCLUSION

METAR data from the stations at Abu Dhabi International Airport, between 2012 and 2022 were used in this study. We have concluded that Fog episodes are more prevalent in the winter, especially from December to February, due to the cool temperatures that result into the temperature inversion at lower levels, that cause the visibility to decline and for the air to be saturated. The average temperature for fog during the winter months at all stations, from December to February is below 25 degrees Celsius, which aids the formation of fog along the calm winds. We used the WINDROSE application to assess variations in the wind. In fog days, most of the days are cloudy and have slight SE winds in the winter for OMAA. Three cases of fog events were analyzed using ERA5 and Wyoming Radiosonde data based on the conceptual diagram illustrated by (Weston, Temimi; 2021) that explains the effect of the radiative cooling that causes the sea breeze the transports the moisture to the land to weaken. Which results in surface inversion layer to form that can cause the dew point to be reached and fog forms.