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EVENT BASED FOG CHARACTERISTICS OF ÇARŞAMBA AIRPORT

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ABSTRACT

In this study, the characteristics of fog events were examined at Çarşamba International Airport in Turkey. Historical meteorological observations were used between the years of 2008 and 2017. Fog events were classified by a simple conceptual model on fog formation process. Fog types, visibility, duration, wind direction and speed, sea surface temperature were reviewed. Results show three main fog types; radiation, advection and cloud base lowering. No fog events were observed between July and September, whereas the most foggy periods were between the beginning of January and the end of May. This corresponds with the advection fog period. Sea surface temperature and weather temperature was found as highly correlated with each other during fog onset. The return period of dense fog for two years was determined to be 8.27 hours. Light, calm and eastern directions of wind were detected during the most of the fog events. Fog onset and dissipation times were figured out in monthly scale and the effect of solar radiation was clearly seen with the onset and dissipation processes. Determined characteristics of fog in Çarşamba airport can be useful for future modeling studies.

Keywords: Çarşamba Airport, Fog, Fog classification

1. INTRODUCTION

Fog is one of the hydro-meteorological phenomena which has negative effects on human activities, but mainly on transportation. Fog also has a role on the hydrological cycle in exchange of water from atmosphere to the earth's surface. Fog is defined as visibility that is reduced to less than 1000 meters by microscopic water droplets or ice crystals and it occurs near the earth's surface within the atmospheric boundary layer. Despite its importance on human life, physics and characteristics of fog have not yet been completely understood [1].

Research on fog characteristics enhances our understanding of fog climatology and physics. Airport meteorology observations have appropriate resolution data in temporal and spatial scales. The characterization of fog is mainly achieved during foggy days or fog events. The number of studies carried out about fog, mainly focus on the physical experiments, numerical models, artificial dissipation, forecasting/nowcasting, remote sensing, observation technologies, climatology and typology from the beginning of the 20th century [1]. The first climatological studies were done based on the number of foggy days [2, 3] and identification of seasonal characteristics [4]. Definition of fog events and classification of fog types were studied by Meyer and Lala [5]. Tardiff and Rasmussen [6] studied the fog climatology of the New York Region, while Von Schalkayk and Dyson [7], Stolaki et al. [8], De Villiers and Von Heerden [9] examined fog characteristics for Cape Town, Thessaloniki and Abu Dhabi Airports respectively. Additionally, Akimoto and Kusaka [10] classified the fog events over Japan based on event data.

Trend analysis of fog was studied by Hanesiak and Wang [11] for the Arctic regions of Canada. Some other trend analyses were carried out by Forthun et al. [12] for southeast USA and La Dochy [13] for the Los Angeles regions. Integrated effect of urbanization and climate change alters fog characteristics of different regions as decreasing or increasing trends of fog events in intensity and frequency in regards to the Clausis-Clapeyron equation.

Fog studies are very limited over Turkey. Ozdemir et al. [14] studied fog characteristics of Ataturk Airport and Camalan et al. [15] classified Esenboğa Airport fog characteristics by using foggy days in

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regards to thermal characteristics. Aktaş and Erkuş [16] studied fog and logistic relations for the city of Eskişehir. Investigative reports of fog in Turkey were published by the State Meteorology Office (MGM in Turkish acronomy) in 1984 [17] and climate of Samsun includes some fog characteristics which was published in 1971 by MGM[18]. There is no special study for the Çarşamba Airport and the fog events of the Black Sea regions of Turkey.

This study aims to determine the fog characteristics of Çarşamba Airport. Section two presents the study area, dataset, and methodology used. Section three contains the results of time series analysis ; such as fog event occurrences, seasonal and yearly distributions, onset and dissipation times, and fog types. A brief summary and conclusion is given in Section four.

2. DATA AND METHODOLOGY

Çarşamba Airport (ICAO code LTBF) is located 5.5 meters above sea level near the Black Sea over the Çarşamba plain in Turkey (Lat: 41,2565 and Long: 36,5539) (Figure 1). It is situated in a flat plain and open to wind from the sea in all directions. Çarşamba Airport has 1.5 million passenger capacity / a year as domestic passenger and one-third of these pessengers are international. Seven flight diversions were occured in 2018 as regards to fog events.More than 1.5 million passengers used the airport for their domestic and international flights in 2018 and air traffic is intensifying day by day in regards to the central position of Samsun in its region.

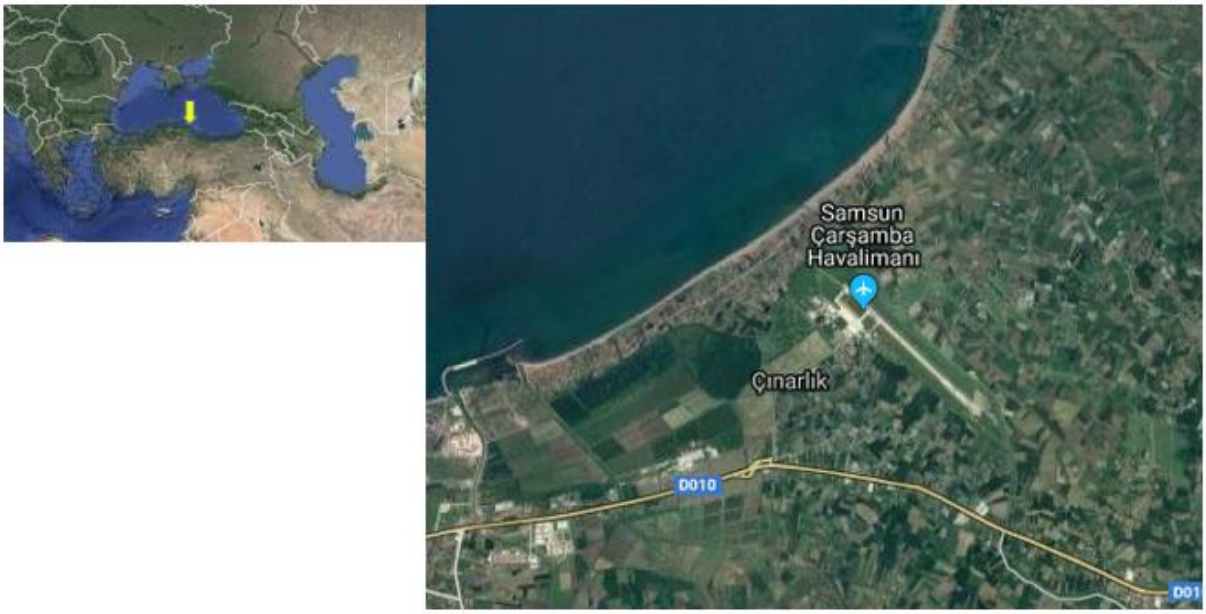


Figure 1. Location of Çarşamba Airport, (USGS Earth Explorer, 2018)

METARs (Meteorological Aerodrome Reports) and SPECIs (Special Meteorological Aviation Reports; which are issued when a significant change occurs in weather conditions) were used to analyze the fog characteristics of the airport. Measurements or observations of surface temperature, visibility, wind speed and direction, precipitation, cloud coverage and base height data were obtained between 2008 and 2017. Sea surface temperature data belongs to the central meteorology station of Samsun Regional Directorate.

In this study, classification of fog events are based on the methodology proposed by Tardiff and Rasmussen [6]. Methodology uses a conceptual model for classification of fog formation process and identifies the five main fog types of precipitation, radiation, cloud base lowering, evaporation, and advection fog. Identification of fog events was based on a decision tree which started five hours before the onset of fog (Figure 2). The decision tree uses the physical formation mechanism and fog formation

characterization. The main mechanism of radiation fog is radiative cooling. Moreover, low cloud coverage and also low wind speed are the main drivers. Advection fog occurs when the warm and moist air meets with a colder land or sea surface air mass, and needs higher wind speeds. Precipitation fog's main mechanism is the evaporation of precipitation. Evaporation fog forms by radiative warming of surface water associated with increasing temperature. Cloud lowering fogs form when stratiform clouds moisten by radiative cooling and subsidize to the land surface. If the fog event cannot be categorized in five of the groups, it is defined as unknown category.

Fog events were identified as atmospheric visibility less than 1600 meters for at least three hours within five consecutive hours and at least one horizontal visibility record for less than 1000 meters during this period. The fog events were used rather than foggy days, because weather phonemena is not confined to time boundaries. The foggy days approach was not used in order not to calculate a fog event before 00:00 twice for each consequent day.

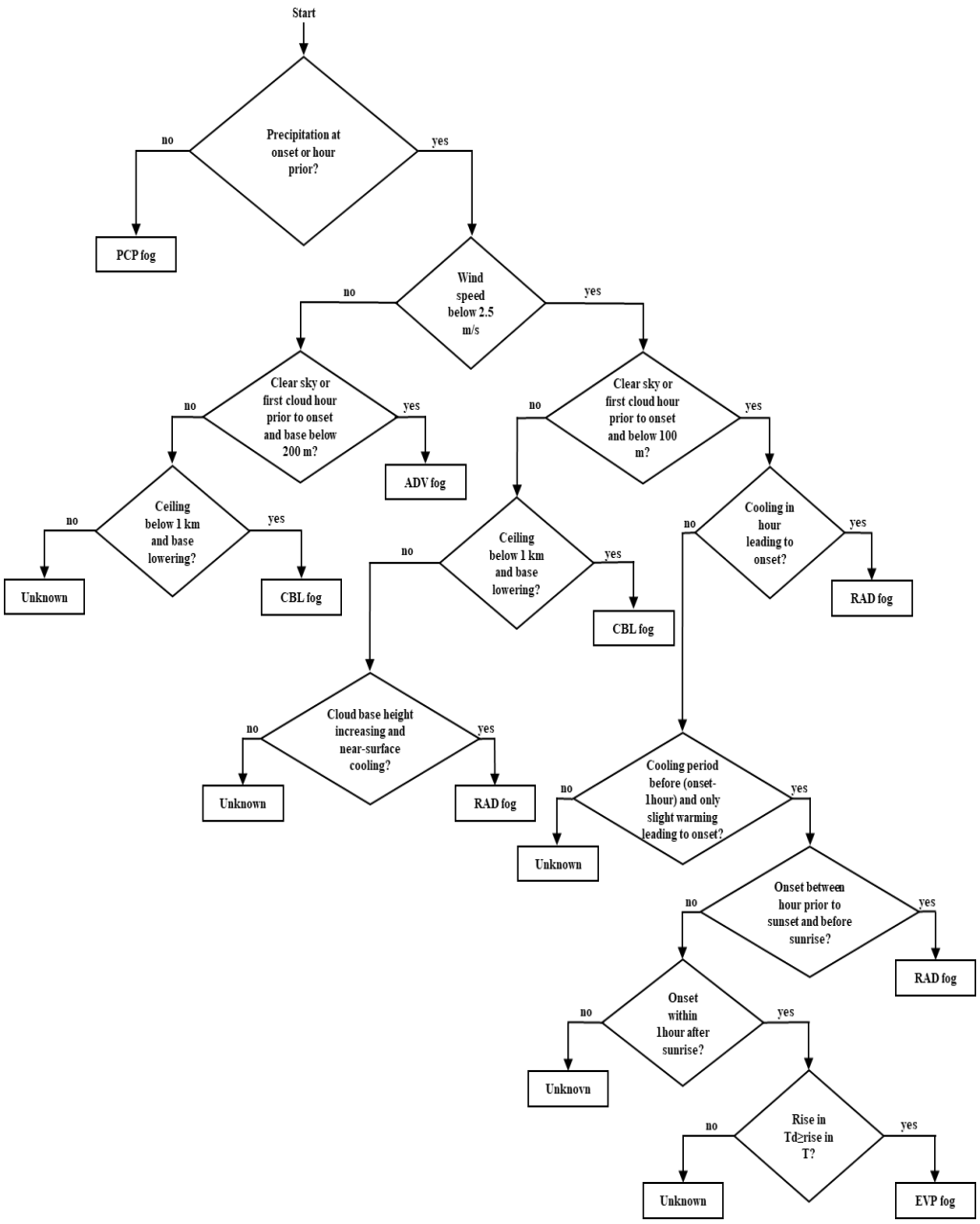


Figure 2. Fog Characterization Chart [6]

3. RESULTS

According to the definition, the number of fog events are sixty-one, with an annual average of six events for the study period (Figure 3). Maximum fog events were detected as nine within the years 2008 and 2014. The minimum event number was two in 2013. Fog events were mostly observed between the end of winter (February) and in the spring months (March, April and May) with the ratio of 80% (Figure 4). No fog event was detected in July, August, and September. All fog events are categorized as warm fog events in regards to air temperature during the event. Fog type classification methodology identified all the sixty-one events in the main three categories. Precipitation and evaporation fog types were not detected. The most common type was radiation fog with the frequency of 54%. The second type was advective fog and the last one was cloud base lowering fog with frequencies of 26% and 20% respectively.

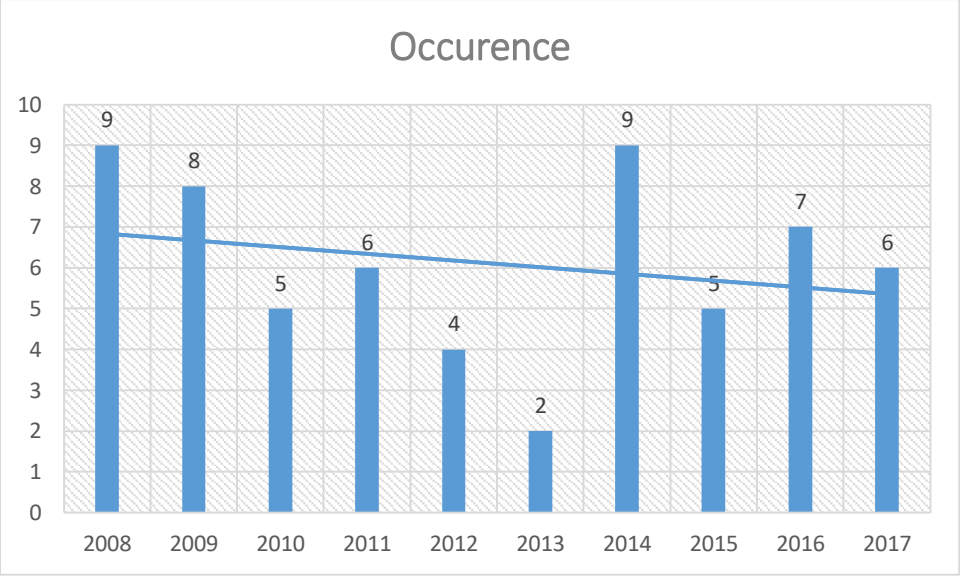


Figure 3. Annual Distribution of Fog Events Between 2008 and 2017

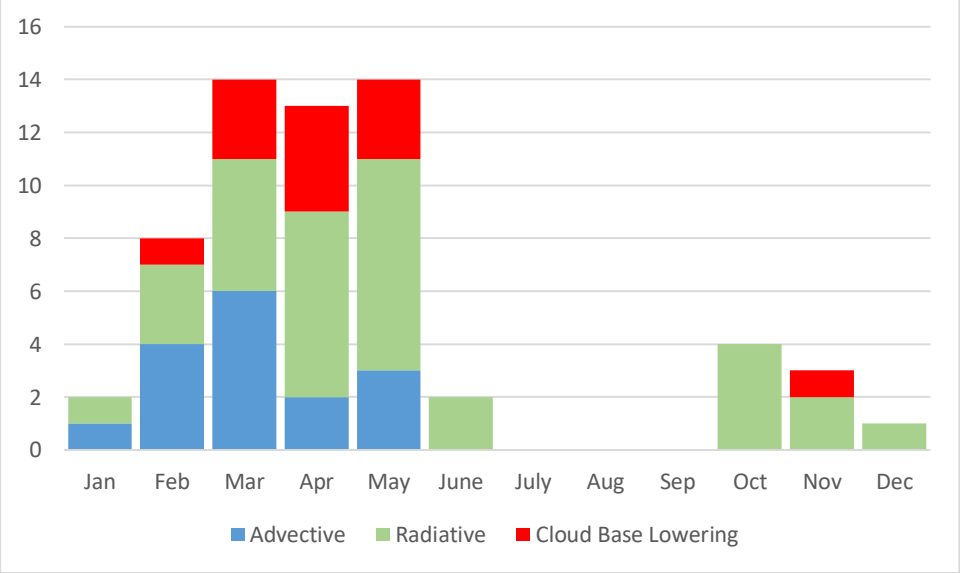


Figure 4. Monthly Distribution and Types of Fog Events (2008-2017)

Onset time of fog events change with seasons in parallel with the sunset time (Figure 5_a), while 91% of the onsets are between 17:00 and 02:00 as a result of radiative cooling acting as the main or secondary role for fog formation. The dissipation time is shown in Figure 5_b. Dissipation times correspond with right after the time of sun rise. This characteristic is more significant for April and May. The main driver is solar warming for the fog dissipation process. Dense fog is defined by horizontal visibilities of ≤400 m accompanied by a reported fog observation [19]. The total fog duration covers 750 hours for the study period and only 22.5% of is categorized as dense fog according to the this definition (Figure 6). Results show that 65,6% of radiation fog events have equal or shorter than 6 hour duration. The maximum duration is 14.3 hours during an advective event . Fog events due to radiation and cloud base lowering fogs have similar average durations. The average duration of advective fogs (8,3 hours) are higher than the other two types. The average minimum horizontal visibility was observed during radiation fog events.

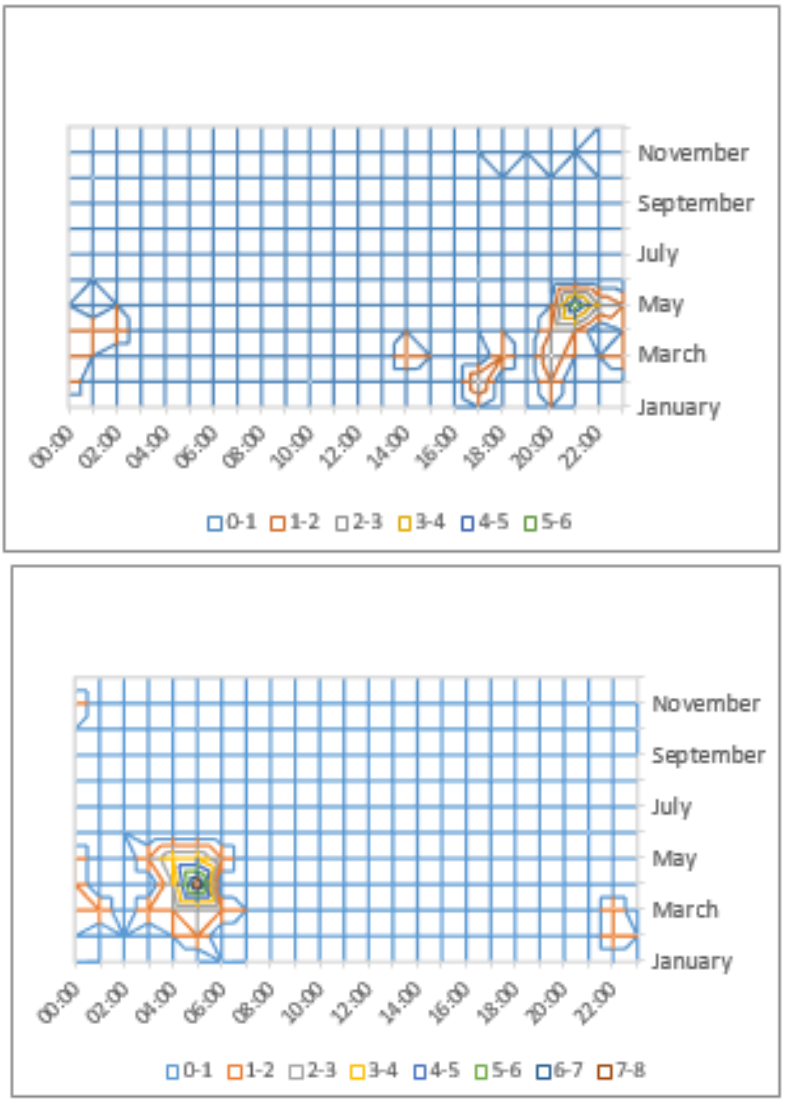


Figure 5. Onset and Dissipation Times of Fog Event (UTC)

Frequency analysis of dense fog duration indicates that a hundred year return period is 11.43 hours and the other return periods are given in Table 1. The distribution type was checked by the Kolmogrov – Simirnov test with a confidence level of 0.05 and was identified as a Pearson Type-3.

Table 1. Extreme Value Analysis of Fog Event Duration

Distribution Type/Return Period	**2**	**5**	**10**	**25**	**50**	**100**
Pearson Type-3 (Gamma Type-3)	8.27	9.77	10.38	10.92	11.21	11.43

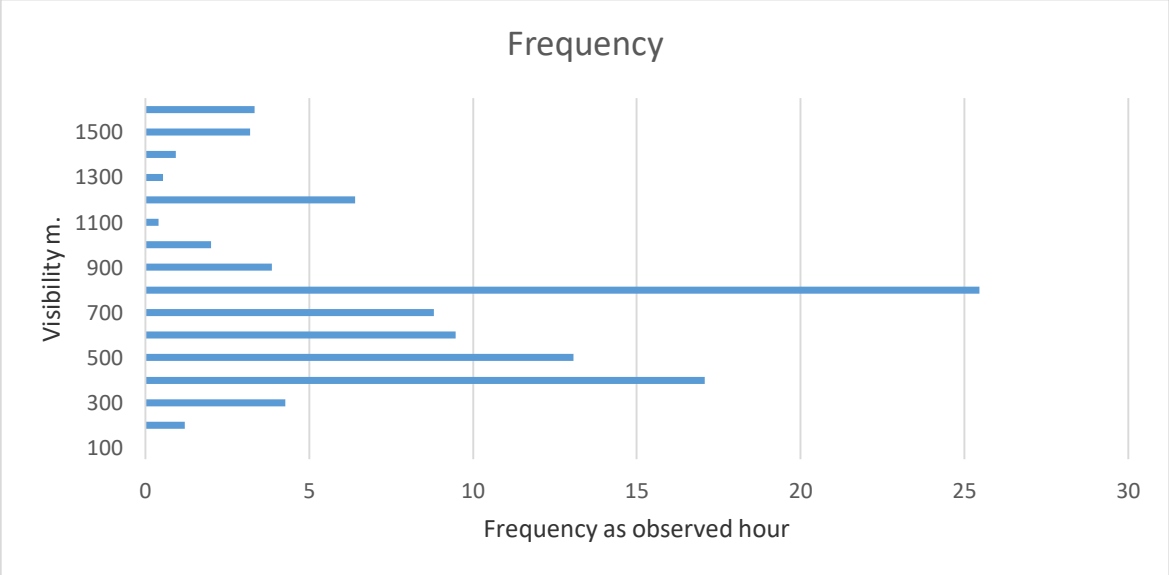


Figure 6. Frequency of Visibility During Fog Events

The winds were calm for 11.1% of the events and E, SE and SSE directions corresponded to 50% of the events. Variable direction with speeds between 0-1 m/s were recorded as 28.2. Only 1.5% of wind speeds were higher than 4 m/s during the events and during these foggy hours the wind was from westerly directions (Figure 7).

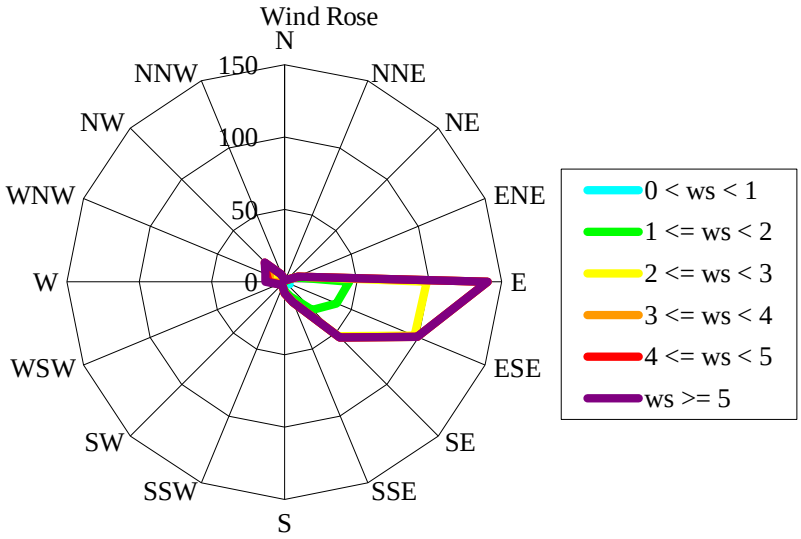


Figure 7. Wind Directions During Fog Events

The average sea surface temperature is higher than the weather temperature during March and April. The difference is smaller in January, February, May and June. This period makes the physical conditions

suitable for the advection fog formations considering the daily minimum air temperatures of the study area.

The air temperature and sea surface temperature during the fog onset time were found as highly correlated with each other for all the detected fog events . This can be a tool for the forecasting of fog onset time. The determination coefficient of the correlations for radiation, advection and cloud lowering fog types are 0.68, 0.76 and 0.87 respectively.

As a case study, an advective fog event was examined with ECMWF ERA Interim reanalysis data over Black Sea Region on 26-27 January 2016 Figure 8. The duration of this fog event was 12.1 hour Figure 8 shows the spatial extent of relative humidity. Observations obtained from Çarşamba Airport and ECMWF reanalysis data are compatible with each other. Advection from the Black Sea to Çarşamba Airport is clearly seen from the humidity maps with six hour interval.

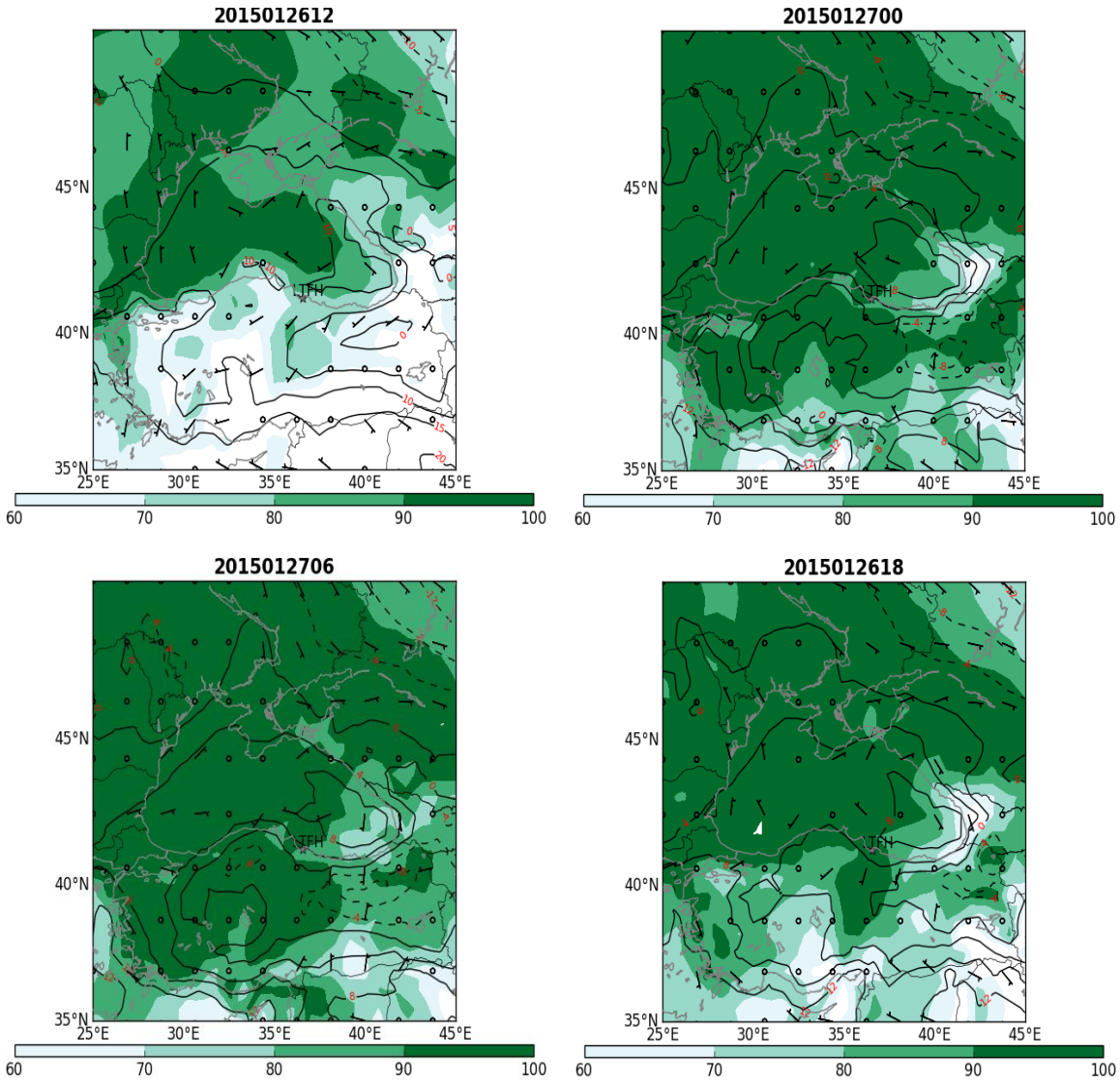


Figure 8. Fog Event over Black Sea on 26-27 January 2015

4. SUMMARY AND CONCLUSION

The objective of this study was the characterization of fog events on Çarşamba Airport. For this reason, a simple typology tool based on formation mechanism was used with the help of meteorology observations of the airport. Main characteristics of fog; namely types, density, duration, wind speed and sea surface temperature were examined.

1. Three main categories of fog type were detected. The most frequently observed fog type was radiation fog. The second and third fog types were advection and cloud lowering fogs respectively. Precipitation and evaporation fog types were not classified during this study period.

2. Seasonality of fog events were very significant. Advection fogs formed between January and May (winter and spring). Radiation fog was seen during all foggy months. No fog event was observed in July, August and September.

3. Sea surface temperature and the weather temperature during onset are highly correlated with the formation of fog events for all three types. This can be a tool for predicting fog onset time over the airport especially for the radiation fog as regards to it's the highest correlation ratio.

4. For the two year return period of dense fog, duration was observed at 8.27 hours in regards to extreme value analysis. Fog event frequency analysis may be a useful tool for the risk analysis of flight security and diversions.

5. The prevailing wind directions were E, SE and SSE during 50% of the events. The wind was calm (11%) and weak (0-1 m/s) with variable directions (VRB) for 28.2% of the events.

6. Fog onset and dissipation times also shows seasonality. Fog onsets were mainly between 20:00 and 24:00 UTC in winter and spring months. Dissipation times were between 04:00 and 08:00 UTC. The main driving force is radiative warming in regards to sunrise.

7. A case study of an advection fog on January,2015 showed that the ECMWF ERA Interim reanalysis data (humidity) were consistent with the observations of Çarşamba Airport Meteorology Station. Numerical models are capable of detecting the relative humidity content of the air but the visibility tests are on the way.

Characterization of fog put forth in this study can be used as a tool for fog prediction at Çarşamba Airport. Determination of common dense fog duration can be useful for air traffic planning studies. On a larger scale, this study contributes to the characterization of fog for the Black Sea region, in which limited fog climatology studies have been carried out thus far.

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