A synoptic/statistical analysis of dense fog event near the Caspian Sea

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To improve aviation forecast in Rasht International Airport (RIA) near to Caspian Sea coast, fog climatology was developed that examines the surface weather conditions at dense fog event. Surface airways hourly observations for the period 2000-2009 were examined focusing primarily on some parameters such as horizontal visibility, temperature, dew point deficit, relative humidity and winds speed. Results show that, the frequency of fog event in the cold months is more than warm months spatially in February. Onset time for long-lasting fog event is more likely between 1800 UTC to 2100 UTC and the horizontal visibility at the onset time is (<100m). End time for each duration categories was close to sun rise. In the most events, dew point deficit and relative humidity at the fog onset time were calculated zero and 80%, respectively. Low wind speeds (0-0.2 ms\(^{-1}\)) were favor for fog development in the area. The most important synoptic patterns in long-lasting fog development are 1) Blocking pattern in the 500 mb geo potential height map2) Singular point region at surface and 3) Temperature inversion near surface in the cold season.

Key words: Fog, horizontal visibility, wind speed, Blocking pattern, Singular point region, Inversion

INTRODUCTION

Large scale atmosphere patterns have a controlling role on small and main size scale phenomena. This patterns lead to development of dense fog with very low horizontal visibility near to Caspian Sea which is very important for airports and could cause great damages on aviation and ground transportation. Since, fog has not been examined in detail in this area. One reason may be that fog is not easily studied by remote sensing measurements such as weather radar and satellite (Ellrod 1995; Bendix et al. 2005). Fog is a boundary layer feature, but also a phenomenon set up by synoptic-scale conditions, and one that sometimes is adversely affected by overlying cloudiness. Consequently, fog is not simple to model or to forecast, particularly for regions such as the Caspian Sea where fog develops under a variety of conditions and where both radiation and advection processes may be important to the formation process. Bromand and Mohamadi (2011) have investigated correlation between fog and some atmospheric parameters such as mean temperature, dew point temperature, relative humidity, wind speed, cloud cover and atmosphere pressure changes in Ardabil Airport and then presented a statistical model for fog forecast. The result showed that, relative humidity is more correlated with visibility and correlation coefficient between visibility and relative humidity in 03 GMT is more than 15 GMT. Visibility is more correlated with cloudiness in 15 GMT. Examination of synoptic patterns has indicated two effective patterns have role in formation of fog: 1) influence of Siberian high pressure that spreads from northwest to northeast of Caspian Sea and 2) Immigrant European high pressure. Rahimi (2011) analyzed the temporal and spatial variation of fog days in Iran. The result showed that the advection fogs are common in Persian Gulf and Caspian Sea regions. Fog predictions are often observationally based (e.g., Herzegh et al. 2004) or model based (Vislocky and Fritsch 1997; Leyton and Fritsch 2004; Bergot et al. 2005). Westcot (2006) suggested fog
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Figure 1. Map of Caspian Sea and district

phenomena is a feature of cold season at the west part of U.S and found that the fog events forming earlier in the night may last longer because of the lack of solar radiation upon the fog layer during the night.

In this study, fog climatology (with a horizontal visibility of 800 meters and less) was developed near Caspian Sea that investigates the surface weather conditions at the time of dense fog. This study is not limited to any one fog type. Indeed, the synoptic pattern associated with long and short duration fog events were identified to now casting the all types of inland dense fog events near the Caspian Sea. The climatology is based on RIA station data. The station is located in the Caspian Sea coast that is minimally affected by topographic and urban effects.

Data and methods

Rasht is the largest city on Iran’s Caspian Sea coast. It has a humid subtropical climate that is very wet for being in Iran. It has certain Mediterranean features such as a drier summer, but is also relatively continental with cool winters that averages far below summer temperatures, in spite of its marine position. The climate is humid year-round, making summers feel hotter than the average temperature. Sunshine hours are very low for a location on the 37th parallel, and is massively low compared with other cities further south in Iran.

One decade of hourly surface airways observations at RIA have been taken from National Weather Service (NWS). These parameters consist of horizontal temperature, visibility, relative humidity, dew-point deficit and winds speed during 2000-2009. Figure 1 shows map of Caspian Sea and RIA locate at south western sea. Horizontal visibility was used to examine the frequency and spatial extent of dense fog days at RIA. Dense fog, as defined by NWS (1988), is fog that decreases horizontal visibility-to-less than 500 m. For purposes of this particular study (Aviation Safety), a dense fog day is defined as a 24-hour day having at least one hourly observation of dense fog with visibility below 800 m. Fog development were divided into three categories such as short (1–3 hours), medium (3–6 hours) and long (6 or more hours)duration.

Based on frequency of dense fog development in the area, RIA was found to be representative of many sites near to Caspian Sea. Also, the synoptic patterns associated with fog development were identified. In order to, sea level pressure (SLP) and geopotential height in pressure levels plots were created using NCEP/NCAR reanalysis dataset.
DISCUSSION

Fog as a cold season feature

Figure 2 shows the monthly distribution of fog days. The frequency of fog event increases (decreases) in the cold (warm) months. The highest frequency of fog events was obtained in February for fog event with the horizontal visibility of 800 meters or less during 2000-2009. The fog phenomena are a feature of cold season in the area.

Frequency percent of fog events on onset times

The highest frequency of fog events occur in the early morning hours nearby sunrise (Meyer and Lala, 1989). However, analysis of dense fog events at RIA showed a difference in onset time for the long and short duration events. For short, medium and long duration, maximum of fog event frequency in onset times happened within the hours of 0000, 0000 and 1800UTC respectively (Figure. 3). The long duration fog events have maximum frequency nearby midnight and for short and medium duration events are same and near sunrise. The highest percent frequency of dense fog event belongs to long duration events that started between 1800 UTC to 2100 UTC (Figure. 3).

Visibility and Temperature

Horizontal visibility was studied to estimate the intensity of dense fog events in RIA (Figure 4). The horizontal visibility frequently has decreased during long duration events. The minimum visibility was 200 m or less for 70% of the long-duration events (Figure 4). The highest frequency percent for all category of fog events belongs to horizontal visibility of 100 m. Therefore, the events with a horizontal visibility of 100 m which start at 1800 UTC to 2100 UTC are more stable compared to other events.
The minimum and maximum temperature throughout the fog development was identified in RIA during 2000-2009. The minimum and maximum temperature was about -5.8 °C in January 2008 and 25.4 °C in August 2003, respectively. There is a limitation about temperature during the fog development with the horizontal visibility of 800 meters or less and we have specified its limitation from -5.8 °C to 25.4 °C.

Frequency percent of fog events base on dew point deficit

In this study, the fog events were categorized based on dew point (difference between dry temperature and dew point; $\Delta T > 0$, $\Delta T = 0$, $\Delta T < 0$). According to Table 1, the dew point deficit for most events is zero ($\Delta T = 0$). Only in one case (30 April, 2001), dew point deficit is negative ($\Delta T = -0.2$) and there was a super saturation during fog event in the area.

Wind at onset fog event

Low wind speeds have been known to favor fog event. In our study, wind speed of fog events were classified to four type such as slow (0 to 0.2 ms$^{-1}$), mild wind (0.3 to 1.5 ms$^{-1}$), light breeze (1.6 to 3.3 ms$^{-1}$) and mild breeze (3.4 to 5.4 ms$^{-1}$). The number of fog events in RIA has maximum value about 280 in the range of 0-0.2 ms$^{-1}$ (Figure 5). The average of wind speed in fall and winter is less than other season. Wind speed is...
considered as one of important factors for fog development in the area. The frequency of dense fog events at RIA was 18% for more than 0.2 ms⁻¹ speed at onset.

SYNOPTIC AND PHYSICAL PATTERNS

In this section the common synoptic patterns that cause dense fog in the Caspian Sea restrict were analysed. We have studied several cases with highest number of fog developments that caused decrease in horizontal visibility to 200 meters or less. We have found three synoptic patterns that accompanied with dense fogs.

**Omega Blocking Pattern**

It has two large troughs on either side of a large blocking ridge. The high pressure covers such wide latitude that the westerly air flow has difficulty going around the high. The region under the omega block experiences dry weather and light wind for a long period of time while rain and clouds are common in association with the two troughs on either side of the omega block. There are two examples (18 Feb 2005 and 18 Feb 2006) of omega blocking patterns that cause dense fog event in RIA (Figure 6). The stable and warm air has advected on the Caspian Sea and causes evaporation of Sea's surface water and lead to development of long duration fog events with minimum horizontal visibility in RIA.

**Singular Point pattern**

A different pattern was observed in some cases at Caspian Sea coast region. In this pattern, two high and two low pressure systems are parallel to each other at the during the fog development in 850 hPa level. The center of this pattern is called a singular point (Bluestein, 1992). This area accompanied with very calm atmosphere and low wind speeds have been known to favor fog. Figure 7 shows Singular point synoptic pattern at 24 March 2007 during the dense fog with a horizontal visibility less than 200 m in 850 hPa pressure level.

**Inversion**

The temperature inversion was identified as the main pattern of the several fog events in hour 0000 UTC with visibility less than 100 meters in RIA. About 57 fog events were reported with horizontal visibility of 800 m or less due to inversion during 2008. Therefore, the radiation is an important process for the formation of inversion in RIA. The radiation inversion generally occurs in places where it cools off a lot at night and is more common in cold
CONCLUSION

Meteorological conditions at dense fog onset and during dense fog events were examined for 2000–2009 in Rasht International Airport (RIA) near to Caspian Sea coast region to improve aviation forecasts at the site. The following are the conclusions of the present study:

1) During the study period (2000-2009), 356 fog events with 800 m horizontal visibility or less were reported for RIA. Fog event is identified as a feature of cold season (October to March) as 75% of all events and the highest rate of fog event belongs to February.

2) As longer duration fog events often become denser and more widespread than short duration events, more day. Duration fog events related to onset time and the fog event between 1800 UTC to 2100 UTC are more stable and 74% of long term events (more than 6 hours) are developed in this period. End times for each duration classifications were close to sun rise.

3) There is a limitation for temperature during fog development and it changes between -5.8 °C and 25.4 °C for all cases.

4) About 82% of fog events started with wind speed about 0-0.2 ms⁻¹. Low wind speed creates a suitable condition for development of fog event with horizontal visibility of 800 meters or less in RIA. Winds at dense fog onset did not prove to be useful in differentiating between short-(1–2 h) and long- (>5 h) duration dense fog events.

5) Blocking pattern with anticyclone over the Caspian Sea in upper level map (500 hPa) plays an important role for forecasting fog development and minimum horizontal visibility in future days.

6) Identifying Singular point area pattern in SLP and low level map such as 850hPa could have an important role for fog development in RIA.

7) Radiation inversion is known as one of important factors for forecasting nowcasting the all duration category of inland dense fog events.

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