Fog Hazards in Punjab

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Abstract

Using 30-year (1976-2005) real meteorological data of 10-weather stations, four dense fog years (1998-1999, 1999-2000, 2001-2002 and 2002-2003) were investigated. Daily, ten-days and monthly temperature and moisture data of these four years showed significant changes during the fog events. It is observed that day time temperature decreases and night time temperature increases during fog events but the mean temperature remains below 15.5 degrees Celsius, mean relative humidity examined more than 80% for the north Punjab and more than 70% for the south Punjab and throughout the fog period, daily saturation vapour pressure deficit found below 1 hPa. The synoptic charts for these years showed that moist currents continuously penetrate into Punjab from Bay of Bengal and a trough forms over this region. At the same time a high pressure area develops near the foot of Himalayas. Similarly, 850 hPa charts revealed that a trough persists over this area and also a ridge is present to the north east of this region. This work would be helpful to understand the reasons of fog development during winter season in Punjab and to predict the phenomenon before time to minimize the impacts on daily public life and agriculture.

Introduction

Fog is a natural phenomenon and is formed when water vapours in the air begin to condense into liquid water near the surface. Like other parts of the world, Pakistan also has a fog season which starts from November and ends in January. This fog is classified as radiation fog. The fog does not occur across the whole country but only plain areas experience this hazard, particularly Punjab, which is the most affected area that is situated in the north-east of Pakistan.

The frequency of fog has increased in this area after mid 1990s; it is an unusual phenomenon and lasts many days without any break, sometimes sun is not to be seen for many days. Sometimes it is so dense that one cannot see more than a few meters ahead. Because the population and industrialization has increased rapidly in Punjab during the study period, it has to be a polluted atmosphere as well providing extra nuclei for fog droplets to form upon. It affects every field of life. Aviation, road and rail traffics are badly affected by this prolonged fog and the country has to face big economic losses by this hazard.

Roach (1995) illustrated that radiation fog occurs in moist air under clear skies, the rapid loss of long-wave radiation to space allowing the formation of a marked surface-based temperature inversion that captures air near to the surface

Air pollution has strong interactions with fogs and clouds (Acker et al., 2002). The lower layer of the troposphere is rich in aerosols and gases, and therefore it gives an opportunity for fog to develop. Because fog droplets are much smaller (nearly 100 times) than rain drops, they are more concentrated than rain and mass transfer does not limit the kinetics of fog droplet reactions (Lange et al., 2003). The financial and human losses related to fog and low visibility became comparable to the losses from other weather events, e.g., tornadoes or, in some situations, even hurricanes (Gultepe et al., 2007).

Data and Methodology:

The data set of 30-years between 1976 and 2005 was compiled from the Regional Meteorological Centre Lahore, sub-office of the Pakistan Meteorological Department, which was provided after careful quality control. In Punjab, fog occurs only in the winter months of November, December and January but normally the peak fog months are December and January. Maximum temperature, minimum temperature, relative humidity and visibility data was collected for 10-observational weather stations, i.e. Lahore, Faisalabad, Sargodha, Sialkot, Islamabad, Murree, Jhelum, Multan, Bahawalpur and Khanpur. These stations were selected taking into account the length and completeness of records, so that most of the

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region was covered by the corresponding data. Daily data of 10 stations has been analysed in this study to detect the number of days and period of fog in the study area (Figure 1)

NCEP/NCAR re-analysis 1 project has also been used to find the changes in the atmosphere for the period November 1976-January 2005.

Results

After analysing the 30-years (1976-2005) of mean monthly maximum and mean monthly minimum temperatures for the months of November, December and January for all the 10 stations of Punjab, a decreasing trend is found in the mean monthly maximum temperature while an increasing trend is observed in the mean monthly minimum temperature. The 15-year temperature time series indicated that during the last 15-years (1991-2005), the mean monthly maximum temperature decreased and the mean monthly minimum temperature increased. Almost same results were found for all stations considered in this study. In this paper, the results of only one station (Lahore) have been presented.

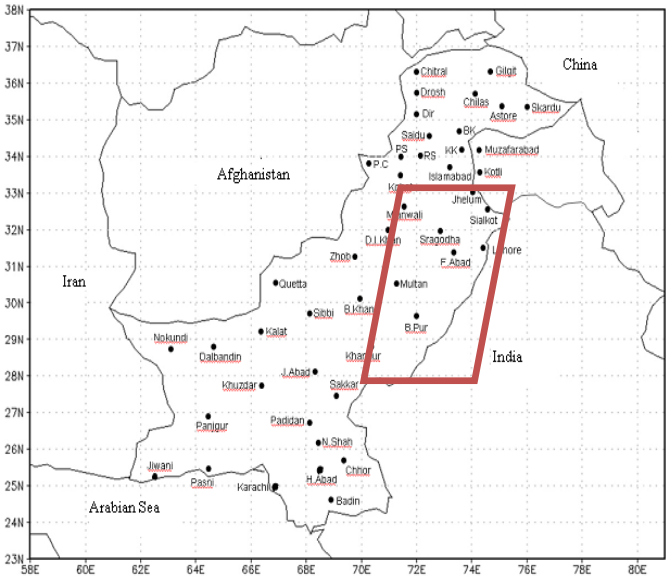

Figure 1: A Map of weather stations of Pakistan, the highlighted area is the Punjab observatories
(Pakistan Meteorological Department)

Daily (NDJ) Mean Temperature Analysis (Lahore):

During this study, four years of dense fog (1998-1999, 1999-2000, 2001-2002 and 2002-2003) have been examined and the daily mean temperatures for the months of November, December and January for these years for Lahore centre are plotted shown in Figure-2 (a, b, c, d) and shaded areas are the fog days.

The starting days of these four fog years are as follows; during 1998-1999 fog started from 12th December (42nd day) 1998; fog began on 1st January (62nd day) 2000 during the 1999-2000 year; fog commenced on 26th December (56th day) 2001 during 2001-2002 year; and fog started from 1st January (62nd day) 2003 during the 2002-2003 year. This time series indicates the chances of fog development would be high when the daily mean temperature drops below 15.5 degrees Celsius.

10-Day Normal Temperature Analysis:

The 10-day mean temperature (NDJ) normal (1976-2005) and daily mean temperature (NDJ) (dashed line) for the years 1998-1999, 1999-2000, 2001-2002 and 2002-2003 are plotted in Figure-3 (a, b, c, d) below and shaded areas are the fog days.

Figure-3 (a, b, c, d) indicates that 10-day daily mean temperature (NDJ) for all the four fog seasons remained below the 10-day mean temperature normal (1976-2005) during fog days.

Daily (NDJ) Mean Relative Humidity (RH) Analysis (Lahore):

Time series of daily mean relative humidity of November, December and January for four fog years is demonstrated in Figure-4(a, b, c, and d) and fog days are shaded.

This analysis indicates that when daily mean relative humidity gets near to 80%, then fog may occur.

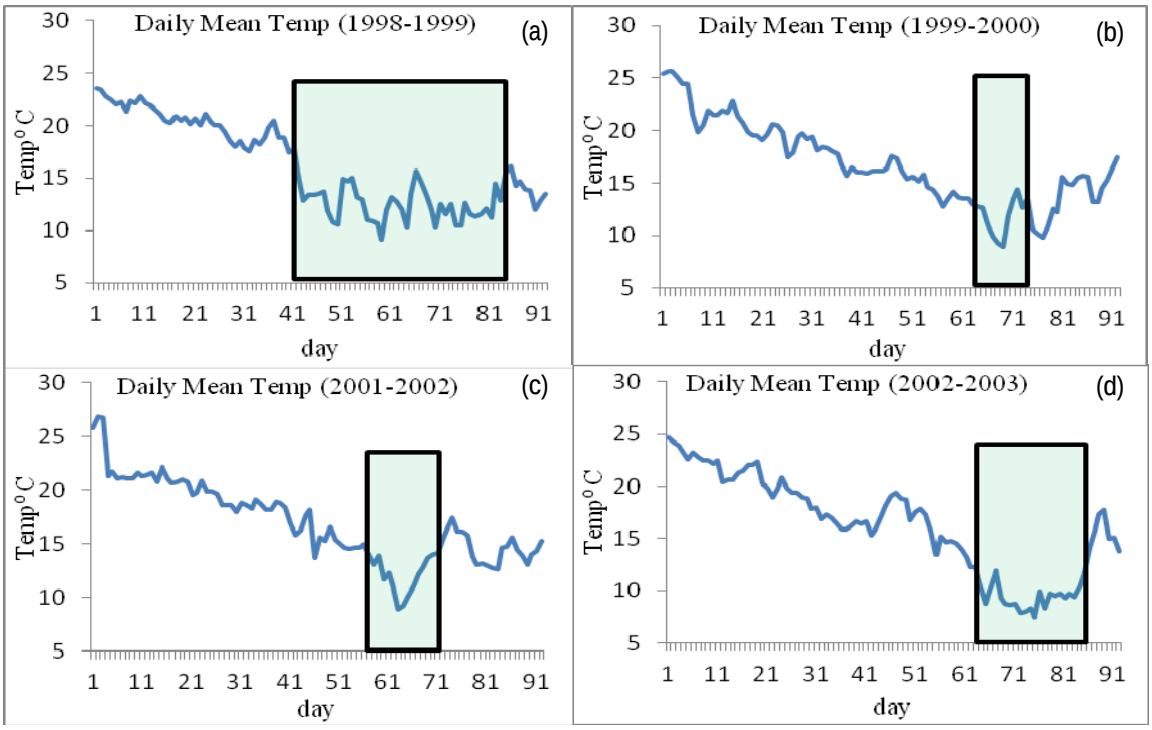

Figure 2: Daily mean temperatures (1998-2003)

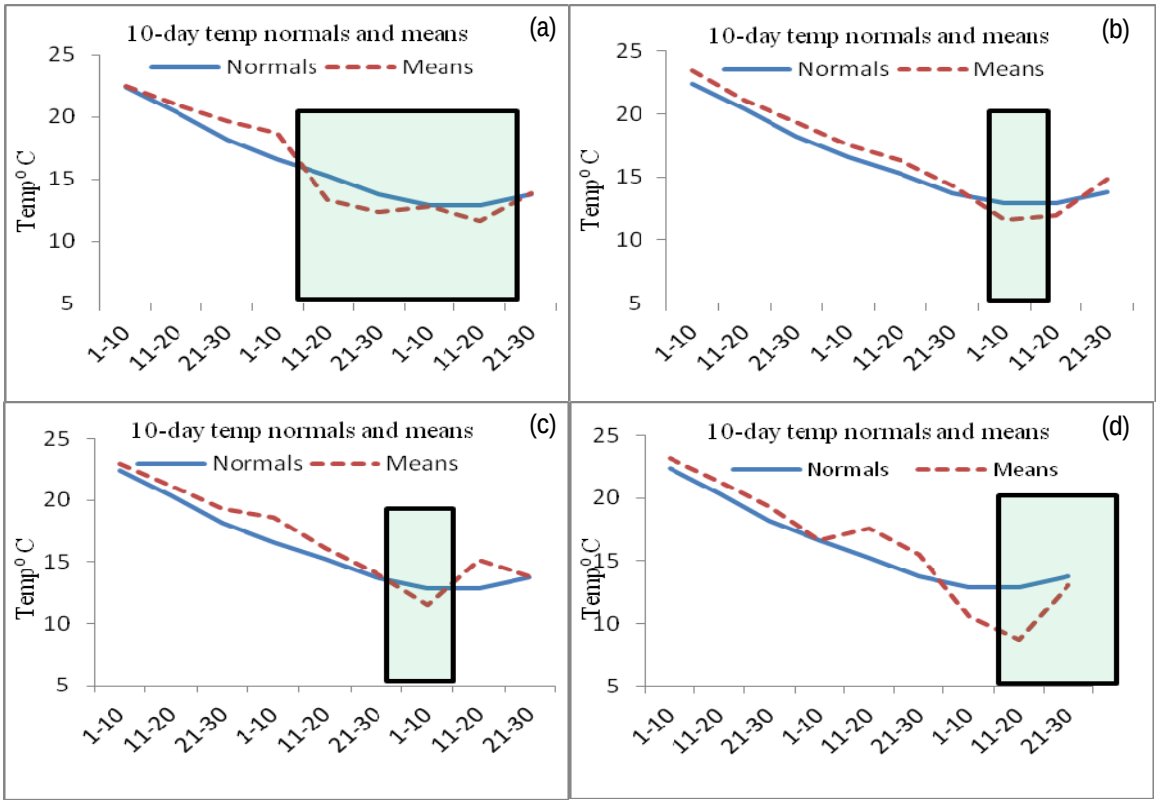

Figure 3: (a) 10-day temp-normal (1976-2005) and daily mean temp (1998-1999) **(b)** 10-day temp-normal (1976-2005) and daily mean temp (1999-2000) **(c)**10-day temp-normal (1976-2005) and daily mean temp (2001-2002) **(d)**10-day temp-normal (1976-2005) and daily mean temp (2002-2003)

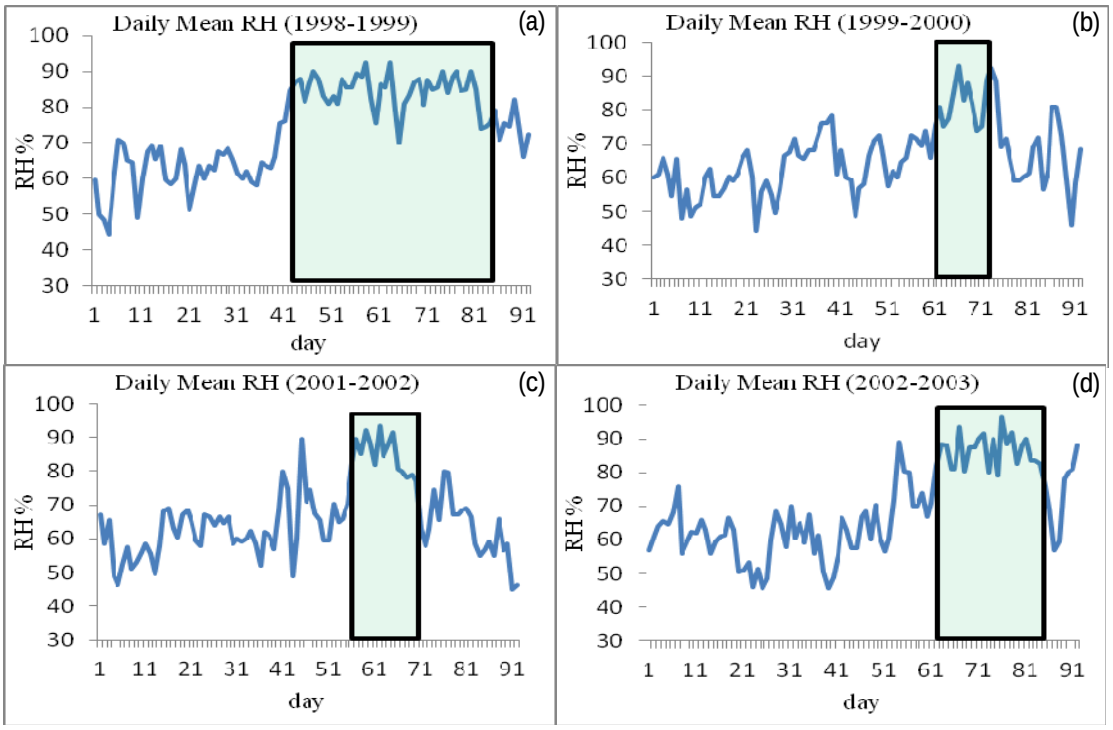

Figure 4: Daily Mean Relative Humidity

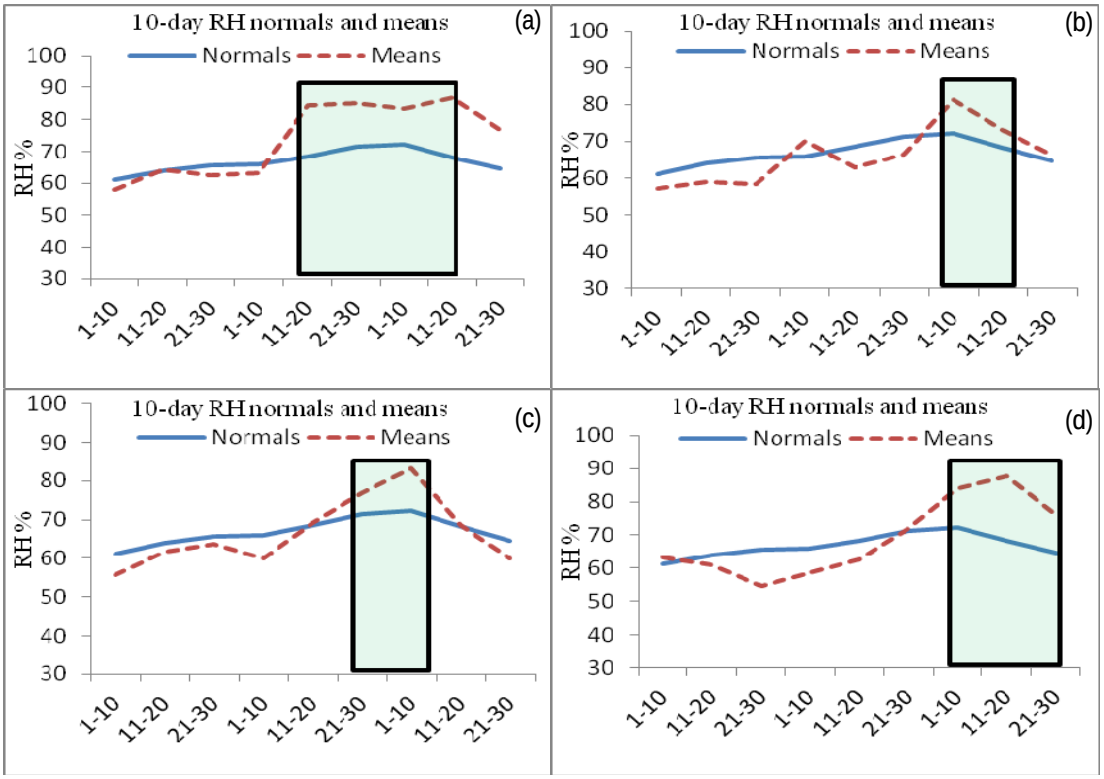

Figure 5: (a) 10-day RH normal (1976-2005) and daily mean RH (1998-1999) **(b)** 10-day RH normal (1976-2005) and daily mean RH (1999-2000) **(c)** 10-day RH normal (1976-2005) and daily mean RH (2001-2002) **(d)** 10-day RH normal (1976-2005) and daily mean RH (2002-2003)

10-Day Normal Relative Humidity Analysis:

Time series of 10-day relative humidity (RH) normal for the months of November, December and January (1976-2005) and daily mean relative humidity (dashed line) of these months for all the four fog years is plotted in Figure-5(a, b, c, d) and fog days are shaded.

This analysis shows that during the fog days for all the four years 10-day mean relative humidity remained above the 10-day relative humidity normal (1976-2005). It means that the atmosphere is more saturated during the fog days.

Daily (NDJ) Vapour Pressure Analysis (Lahore):

The time series of daily vapour pressure deficit for the months of November, December and January for four detected fog years is represented in Figure-6(a, b, c, d) and fog days are shaded.

From this analysis, it is clear that fog may form when the daily vapour pressure deficit falls below 1hPa.

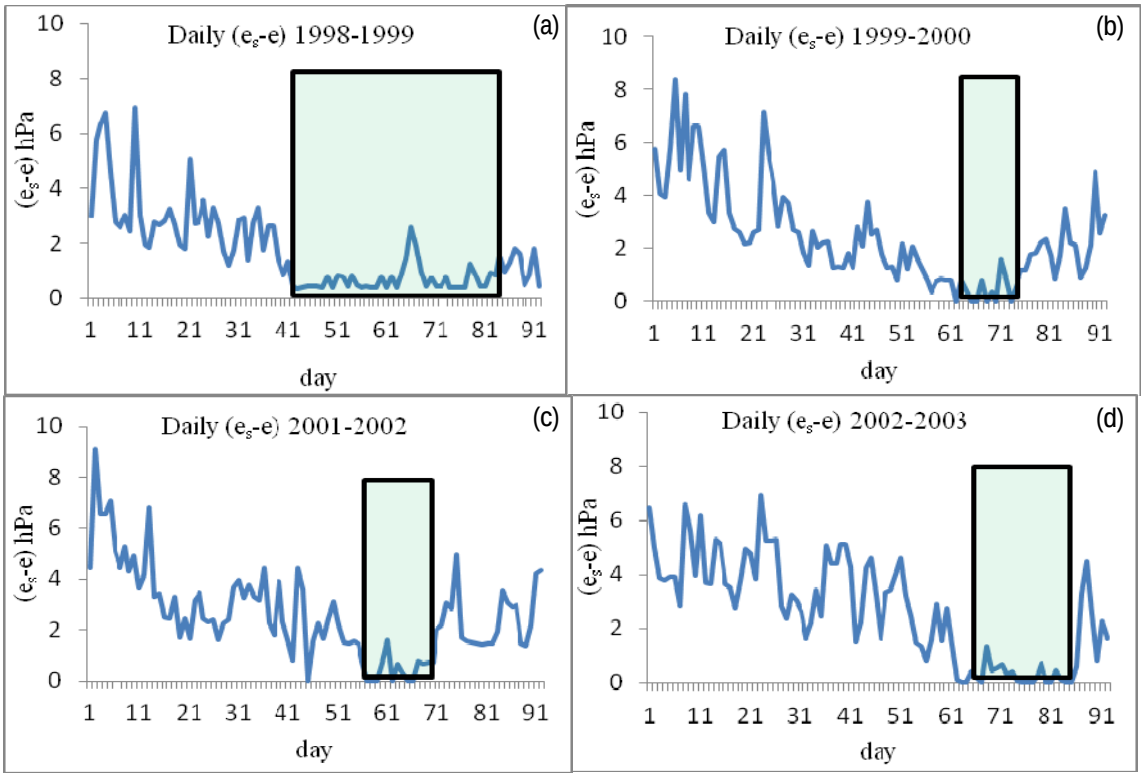

Figure 6: Daily vapour pressure deficit

30-Year Surface and 850 hPa Pressure Charts:

To see the general pattern of atmosphere, re-analysis of surface and 850 hPa pressure charts from NCEP-NCAR for a period of November 1976 to January 2005 has done and is shown in Figure-7(a, b).

The 30-years (1976-2005) averaged surface pressure chart for the months of November, December and January is shown in Figure-7a. This chart shows that a low pressure area exists over central and northern India; its trough is extending up to northern Punjab (Pakistan). A high pressure area persists near the foot of Himalayas and the ridge of this high stretches up to northern Pakistan. Another trough

lies over Uzbekistan and spreading up to north-west Afghanistan. A high over the Caspian Sea exists and its ridge extends up to some parts of the northern Iran.

Figure-7b is the averaged chart of 850 hPa from November to January for a period of 30-years (1976-2005). It is clear from this chart that a low pressure area exists to the north-east India and another low pressure area lies over north and north-east Pakistan.

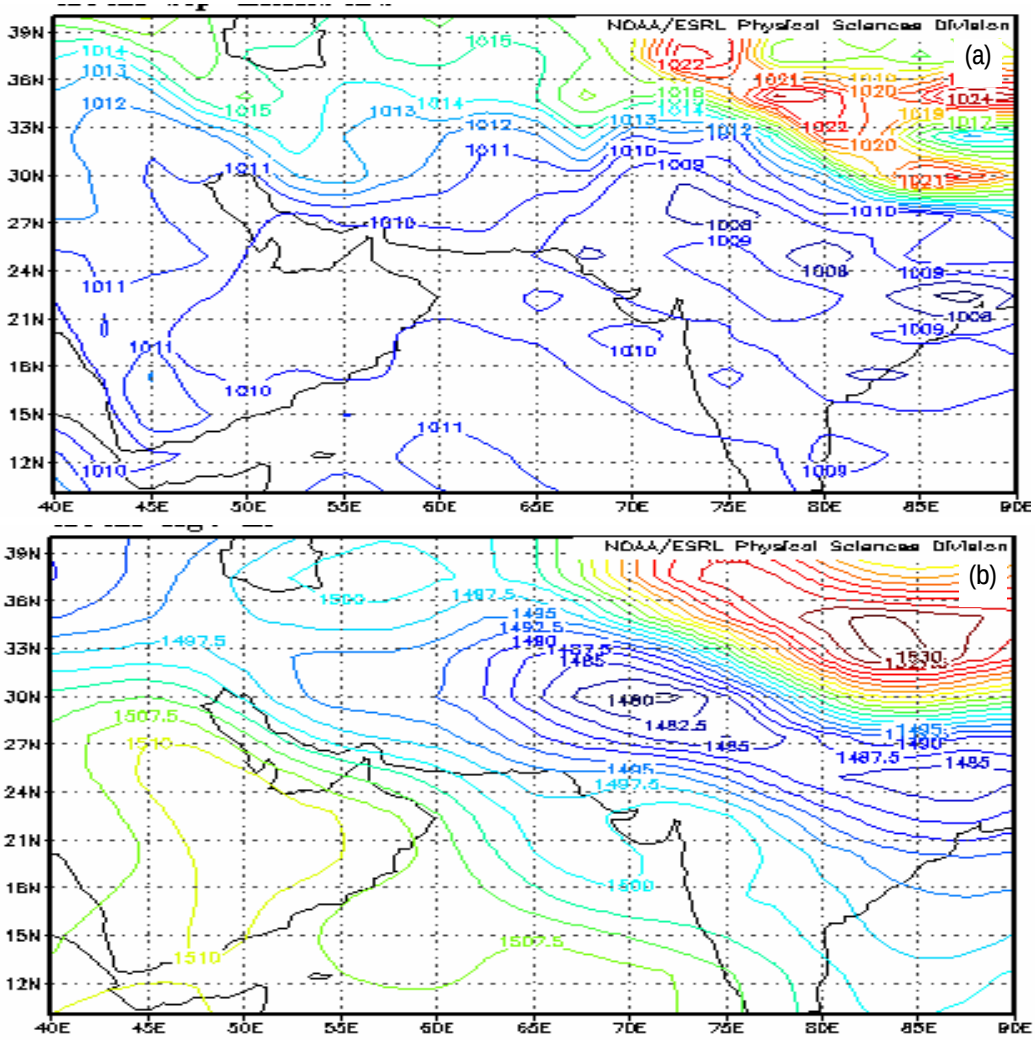

Figure 7: (a) 30-year averaged mean sea level pressure November 1976 to January 2005 (NCEP-NCAR)
(b) 30-year averaged 850 hPa level November 1976 to January 2005 (NCEP-NCAR)

Anomalous pressure plots:

Anomalous plots of sea level pressure (slp) and 850 hPa for dense fog year 1998-1999 (November-January) from NCEP-NCAR are shown in Figure-8 (a, b).

These anomalous plots reveal that during fog months a trough or low pressure persisted over Punjab (Pakistan) and also strong high pressure existed to the west of Himalayas.

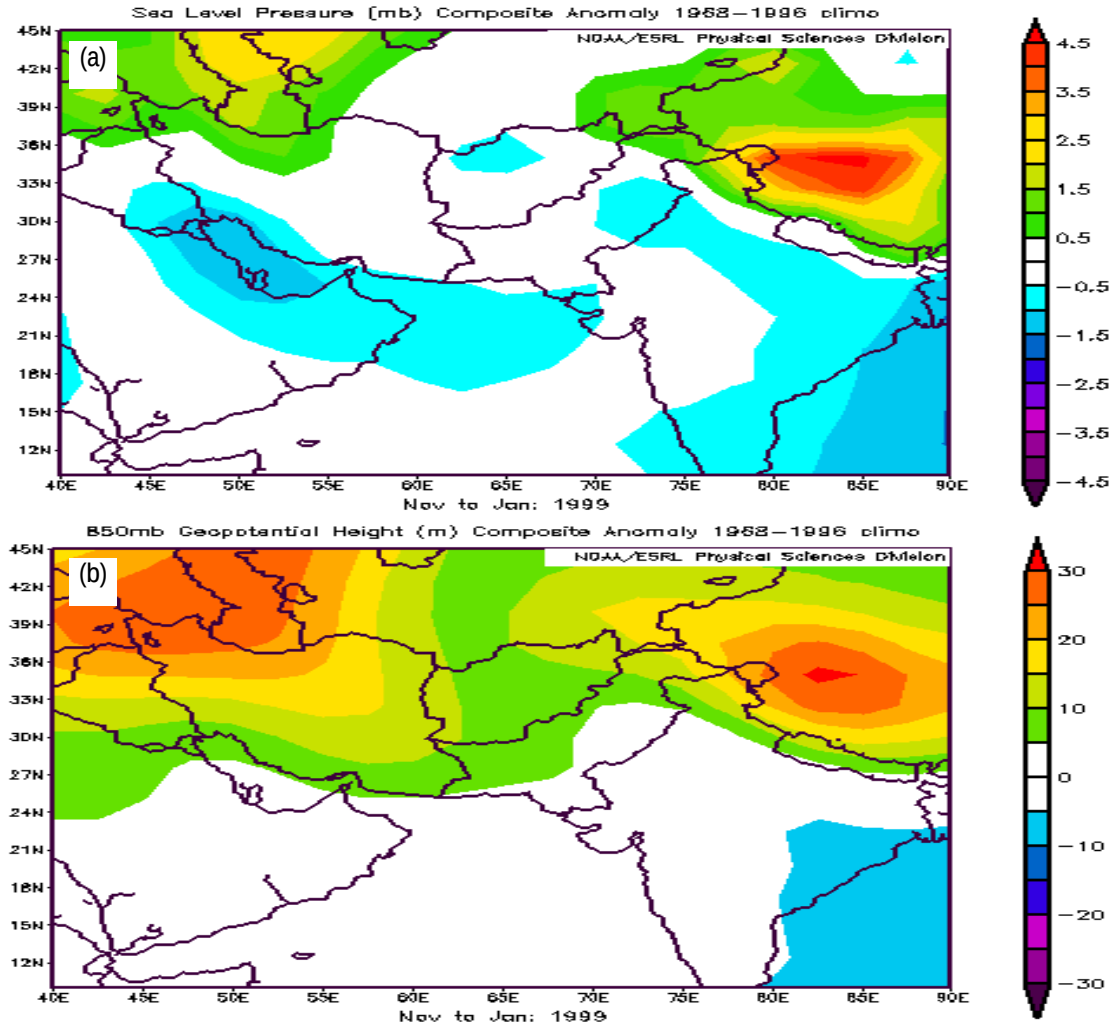

Figure 8: (a) sea level pressure (November-January) fog year (1998-1999) anomaly (NCEP-NCAR) **(b)** 850 hPa level (November-January) fog year (1998-1999) anomaly (NCEP-NCAR)

Discussion

Meteorological conditions associated with fog:

This analysis indicates that during all the four dense fog years, the maximum temperature has decreased because of the reduced solar light and minimum temperature has increased due to the blanket of this fog. It also reveals that fog occurred only when the daily mean temperature and the daily mean relative humidity had a certain threshold value. The daily mean temperatures for all the weather stations of the whole Punjab have a fog threshold value lower than 15.5 degrees Celsius, but the threshold value of daily mean relative humidity for both the north and the south Punjab is different. For the north Punjab, the daily mean relative humidity has a threshold value 80% while that for the south Punjab is 70%. It has also been examined that during the fog days for all the four dense fog years, the 10-day daily mean temperatures have been found to be less than the 10-day normal temperatures (1976-2005). From this result, it is clear that the atmosphere is cooled more during the fog periods. Also it is found that the 10-day daily mean relative humidity remained above the 10-day

normal relative humidity (1976-2005) indicating increased moisture during all the four fog years (10-day normal RMC Lahore).

From the meteorological parameters discussed above, it has been shown that during the fog days the value of daily mean relative humidity is found to be slightly higher in the north Punjab and the value of daily mean temperature is slightly higher in the south Punjab.

The north Punjab is located in the higher latitudes and is close to the great Himalayas. The moisture availability is in abundance in this region due to various rivers, vast canal network and also from irrigated water over vast cultivated wheat fields during winter. In the south Punjab, the Cholistan desert covers a large area. There is a shortage of water, therefore the area under cultivation is small and most of the land lies barren. Some of its parts did not receive rain for a long time. These are the main reasons for the difference between the temperature and the relative humidity of the two parts of the Punjab.

Synoptic features associated with fog:

For the development of fog many meteorological processes operate on different scales and no single process dominates. In addition, fog formation also depends on local features of topography. The mean sea level pressure charts and 850 hPa charts are also helpful for the prediction of fog in Pakistan.

The anomalous mean sea level pressure chart for three months of November, December and January reveals that during the winter months of fog persistence, a low is present over the Bay of Bengal and over southern India and its trough extends up to Punjab. A high lies in the north-east of Pakistan and its ridge stretches towards the west/north-west direction and covers some areas of the northern Pakistan. Another trough lies over Uzbekistan spreading up to north-west Afghanistan. A high over the Caspian Sea exists and its ridge extends up to some parts of the northern Iran. This re-analysis shows that during the foggy months cold and dry air from north-west penetrates into Pakistan through Afghanistan and it stagnates there because of the prominent high pressure present to the west of the foot of the Himalayas where it mixes with the warm moist air coming from the south-east direction. From the above discussion it is clear that for the formation of fog, a trough of low pressure area should prevail over the Punjab and at the same time, a high pressure area must be present to the west of Himalayas.

The anomalous pressure chart of 850 hPa shows that over the Bay of Bengal and some south-east parts of India, a low pressure area exists and its trough extends up to Punjab. In the west of Himalayas and to the north-east of Pakistan a strong high pressure area lies and its ridge stretches to the south-west of Pakistan. An area of discontinuity is found over the Punjab. Another ridge also penetrates through Iran and Afghanistan into Pakistan from the Caspian Sea. In such conditions some deflected moisture at low level (1000-1500) m above sea level penetrates into Punjab through the foothills of the Himalayas.

Conclusions

Four out of 30-years have shown dense prolonged fog events, which are 1998 to 1999, 1999 to 2000, 2001 to 2002 and 2002 to 2003. The dense fog in the study area was observed to be more frequent during the late 1990's, because the population and industrialization has increased rapidly in Punjab during this period. These man-made factors have polluted the atmosphere which also alters regional climate change (Singh et al., 2007). Data analysis of these four winter seasons highlighted the following results during dense fog events;

- Mean temperature analysis of all major meteorological stations examined in this study indicates that fog develops when the daily mean temperature drops below 15.5 degrees Celsius.

- Daily mean relative humidity analysis of all the stations of the north Punjab shows that fog occurs when the daily mean relative humidity attains the value of 80%, and for the south Punjab, the analysis of all the stations reveals that fog develops when the daily mean relative humidity acquires the value of 70%.
- The analysis of vapour pressure deficit of all the stations of Punjab reveals that fog forms when its value falls below 1hPa.
- A low pressure type circulation (or trough) develops at 1000 to 850 mb over the study area (Punjab).

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