Abstract—Thunderstorm is one of the most harmful atmospheric phenomena. The present study examines thunderstorms recorded in Tabriz Synoptic Station during 2000 to 2009. This includes statistical and synoptic analyses (at 500 and 850 hPa levels). According to statistical surveys, most thunderstorm events were recorded in the warm season at 18:00 GMT. The annual data of thunderstorms was fitted to Poisson and negative binomial distributions. The results indicated that the data are only reasonably fitted to a Poisson distribution. According to synoptic analysis, the main reason for the most severe thunderstorm recorded in Tabriz Station is that the station is located in the east of troughs of a low-height center in southern Scandinavia.

Keywords—Statistical analysis, Synoptic analysis, Thunderstorms

1. INTRODUCTION
Thunderstorm is one of the violent natural phenomena which can be associated with heavy winds, hail and severe showers [5]. In general, thunderstorms are formed during three distinct stages including formation of cumulus clouds (developing stage), mature stage and dissipating stage.

A) Cumulus (Developing) stage: In this stage, cumulus clouds are formed. The clouds gradually grow and form larger clouds with a size of 2 to 8 km. Surface pressure reduces several hPa within 5 to 15 minutes. Surface air mass experiences a convergent rotation and thus gradually rises through the whole troposphere. The rising speed steadily increases and may reach 15 m/s [3].

B) Mature stage: This stage lasts about 15 to 30 minutes. While cloud continues rising, water droplets and ice particles in middle parts of the cloud are drawn down due to gravity. The air drawn downward from the upper parts is spread horizontally and causes a sudden increase in pressure, temperature reduction and severe rainfall. In most thunderstorm events, hail phenomenon has been reported at this stage [4].

C) Dissipation stage: When upward flow is gradually interrupted, downward flow is intensified and destruction begins. The interruption of upward flows is associated with the lack of heat and moisture. The lack of moisture results in reduced downward flows. Thus, the amount of precipitation and the extent of precipitation area will decrease and the temperature within the cell becomes approximately equal to the ambient temperature. At this stage, full dispersion occurs and the cell is destroyed [1].

2. MATERIALS AND METHODS

In this research, the data recorded during a 10-year period (2000-2009) with a three-hour interval in Tabriz Synoptic Tabriz was studied. Accordingly, the exact dates of thunderstorm events were extracted. After collecting data, statistical analysis was performed using the Microsoft Excel. Studies includes synoptic and statistical analyses. Statistical analysis includes data quality control (using the Run Test), statistical survey (annual, seasonal, monthly and hourly variations of thunderstorms) and fitting data to statistical distributions. To obtain statistical distributions of thunderstorms recorded in Tabriz Station, the annual data of thunderstorms were fitted to negative binomial and Poisson distributions.

Figure 1: Location of Tabriz Station

2-1- Fitting data to statistical distributions
2-1-1- Fitting data to negative binomial distribution

The negative binomial distribution is calculated using Eq. (1).

\[ f(x) = \frac{p^x (1-p)^k}{x(k; \theta, \phi)} \]

In which:

\[ p = \frac{\theta}{\theta + 1} \quad \text{and} \quad \phi = \frac{1}{\theta + 1} \]

To apply Eq. (1), the following prerequisite should be satisfied [6]:

\[ \left( \frac{1}{\phi} + 1 \right) \left( \frac{1}{\phi} + 2 \right) > 20 \]  

(2)

At this stage, the mean and variance of annual data of thunderstorms recorded in Tabriz Station were obtained and then \( p \) and \( k \) were calculated. To fit data to a negative binomial distribution, the necessary condition given in Eq. (2) was examined.

2-1-2- Fitting data to Poisson distribution

Eq. (3) is used to calculate the Poisson distribution:

\[ \Pr(X = x) = \frac{e^{-\mu} \mu^x}{x!} \quad x = 0, 1, \ldots, \infty \]

where \( e \approx 2.72 \) is naperian logarithm base, \( \mu \) is the mean probability of the event per unit time (or unit area) and \( x \) is the number of days with thunderstorms [2]. In this section, the mean and annual frequencies of thunderstorms recorded in Tabriz Station were first studied. Then, data was fitted to a Poisson distribution and \( \mu \) was estimated. Accordingly, the probability of a certain number of thunderstorms per year in Tabriz Station was calculated.

2-2- Synoptic Analysis

For synoptic analysis, the required synoptic charts at 500 and 850 hPa levels were obtained from NCEP/NCAR website. Thereafter, the charts were studied within an 18-hour timeframe, one day before and one day after the most severe thunderstorm recorded in Tabriz Station.

3- Results and Discussion

3-1- Statistical Analysis

3-1-1- Data Homogeneity

The quality of data was controlled using Run test. The results showed that the homogeneity condition is satisfied.

3-1-2- Annual, seasonal, monthly and hourly surveys of thunderstorms in Tabriz Station
Figure 4: Seasonal frequency of thunderstorms in Tabriz Station

Figure 5: Hourly frequency of thunderstorms in Tabriz Station
3-1-3- Fitting annual data of thunderstorms in Tabriz Station to statistical distribution

A) Negative Binomial Distribution

Table 1: Fitting the annual data of thunderstorms to a negative binomial distribution

<table>
<thead>
<tr>
<th>k</th>
<th>p</th>
<th>Variance</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.53</td>
<td>0.39</td>
<td>17.47</td>
<td>6.8</td>
</tr>
</tbody>
</table>

As shown Table 1, the prerequisite for fitting annual data of thunderstorms in Tabriz Station is to a negative binomial distribution is not satisfied.

B) Poisson Distribution

Table 2: Fitting the annual data of thunderstorms to a Poisson distribution

<table>
<thead>
<tr>
<th>Number of annual events</th>
<th>Poisson distribution per estimated relative frequency</th>
<th>Relative frequency observed for thunderstorms</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.007</td>
<td>0.014</td>
</tr>
<tr>
<td>3</td>
<td>0.058</td>
<td>0.014</td>
</tr>
<tr>
<td>4</td>
<td>0.099</td>
<td>0.014</td>
</tr>
<tr>
<td>4</td>
<td>0.135</td>
<td>0.014</td>
</tr>
<tr>
<td>7</td>
<td>0.149</td>
<td>0.014</td>
</tr>
<tr>
<td>8</td>
<td>0.126</td>
<td>0.044</td>
</tr>
<tr>
<td>10</td>
<td>0.065</td>
<td>0.014</td>
</tr>
<tr>
<td>14</td>
<td>0.005</td>
<td>0.014</td>
</tr>
</tbody>
</table>

According to Table 2, the observed relative frequency of thunderstorms and the Poisson distribution for estimated relative frequency are pretty close. Thus, the annual data of thunderstorms recorded in Tabriz Station are reasonably fitted to a Poisson distribution.

- The most severe thunderstorm recorded in Tabriz Station (29 June 2004)

A) The day before the thunderstorm (28 June 2004, 18:00 GMT)

At the 850 hPa level, a low-height center is located on the north of Iran and its troughs fully covered the north west of Iran. Another low-height center with two closed curves is located in the south and south east of Iran (Fig. 6). At the 500 hPa level, a low-height center is located on the southern Scandinavia and its troughs are extended to the north west of Iran and north of Saudi Arabia with a nearly northern-southern extension (Fig. 7).
B) The day of thunderstorm event (June 29 2004, 18:00 GMT)

At the 850 hPa level, a low-height center with two closed curves is located in the center of Iran. The troughs are extended to East Turkey with a southeast-northwest extension and fully cover the Tabriz Station (Fig 8). At the 500 hPa level, a low-height center is located on Scandinavia and its troughs are extended to southern Iraq with an almost northern-southern extension. Compared to the day before the event, the axis of the trough is extended to the East and fully covered North West of Iran (Fig. 9).

C) The day after thunderstorm event (June 30 2004, 18:00 GMT)
On the day after the thunderstorm, a high-height center with three closed curve was formed on the east of Caspian Sea at the 850 hPa level. This center covers the northern half of Iran. Another centers are located in South Iran and East Pakistan. On the other hand, a low-height center with three closed curves is located on Scandinavia. The troughs of this center became weaker than the previous day and extended to the north of the Black Sea (Fig. 10).

At 500 hPa level, a high-height center is formed on the Arabian Peninsula and parts of Iran and Iraq. The troughs are extended to the Aral Sea with a southwest-northeast extension. However, low-height centers are located on Russia where troughs are extended to the East Mediterranean Sea with little impact on Iran (Fig. 11).

4- Results

According to seasonal analysis, the most and least thunderstorm events were observed in spring and summer (warm seasons) and in autumn and winter (cold seasons), respectively. Since the sunlight falls in the cold season, the surface temperature is lower than in the warm season and thus less thermal energy is available. As a result, the occurrence of convective phenomena (including thunderstorms) in cold season is reduced compared with the warm season.

The hourly variations of thunderstorms suggest that most thunderstorms (at a given time) occurred at 15:00 GMT and 18:00 GMT. This is possibly due to the surface heat during the day, because this accelerates lapse rate of air in the lower part of the atmosphere and increases its vertical movements. So if instability conditions in the region are provided, large volumes of liquid water and ice with a surface temperature of -20°C will be carried and thus thunderstorms occur.

The annual thunderstorm data were fitted to Poisson and negative binomial distributions. The results showed that Poisson distribution reasonably fits the annual data of thunderstorms. According to synoptic analysis (at 500 and 850 hPa levels), the most severe thunderstorm in Tabriz Station occurred because of the troughs of a low-height center located in southern Scandinavia and the location of Tabriz Station in the east of troughs.

5- REFERENCES