Surface and Upper Level Pressure Patterns & Anomalies Associated with Thunderstorms in the Central Part of Saudi Arabia

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Abstract

The surface pressure, the 500 mb geopotential heights, and the 200 mb geopotential height patterns and anomalies that associate with and precede thunderstorms events in the central part of Saudi Arabia were investigated by applying composite techniques. Daily thunderstorms data for Riyadh, Saudi Arabia and daily surface pressure data and 500 mb, 200 mb geopotential height data for the area bounded by 10° N to 90° N and 90° W to 90° E were utilized.

The findings indicate that March and April thunderstorms events in the central part of Saudi Arabia are not only due to a local effect but also come wiith active synoptic system that can be observed in surface pressure as well as different upper levels. Three days before the thunderstorm event day, a meridional pattern develops and dominates the area extending eastward from north America to central Asia with pronounced wave pattern progresses eastward. During the thunderstorm event day, western Saudi Arabia becomes under a deep upper level trough putting the country under a cyclogenesis effect. Also, during the thunderstorm event day, the Red Sea surface pressure becomes more active and extends northward. The finding of this research indicates that the combination of strong Red Sea surface low pressure and deep upper level trough provide the needed ingredient for the development of thunderstorms in the central part of Saudi Arabia. The Surface pressure causes moist southerly wind providing the needed moisture and the upper level pattern provides the lifting mechanism, cooling, and strong jet stream which intensify the instability, thus causing thunderstorms. The findings of this research suggest that it is essential to carefully monitor the upper atmospheric patterns over the east-

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ern Atlantic Ocean, the western Mediterranean, and Europe to improve the thunderstorms forecasts in the central part of Saudi Arabia.

KEY WORDS: Geopotential height Synoptic pattern Mediterranean trough Red Sea low Anomalies Composite technique environmental-to-circulation.

Introduction

Studying the atmospheric patterns associated with a particular climatic and meteorological phenomenon helps to understand the phenomenon and predict it.There are numerous studies about the upper atmospheric patterns associated with thunderstorms in many regions of the world, especially in the United States and Europe where there is enough record of upper level data. However, in places, such as Saudi Arabia, where there is a shortage of upper data there is lack of studies that investigate the effect of the upper atmospheric pattern on the surface climate. The literature review reveals that most of the studies about the climate of SaudiArabia concentrate on the spatial and temporal distribution of climatological parameters, but do not tackle the atmospheric pattern cause or associated with the studied climatological phenomenon. Also, there is shortage of researches that investigate thunderstorms in the country, especially the upper level mechanism associated with thunderstorms. The limited number of studies about the relationship between Saudi Arabia surface climate and upper level parameters such as those of Solot (1950), Takahashi (1981), and Hastenrath (1981) do not cover enough period of time and do not tackle the relationship between thunderstorms in Saudi Arabia and the upper level synoptic pattern. The shortage of study in this field is due to the lack of upper levels data; however, after the issue of the National Meteorological Center CD-ROM data set by the university of Washington and the National Center for Atmospheric Research (NCAR) in Colorado, some needed research data became available. This disc includes data that covers Northern Hemisphere including Saudi Arabia. This allowed investigating the upper patterns associated with surface climatological phenomenon in Saudi Arabia, (Alkolibi, 1995).

Though the study of Alkolibi, 1995, provided a new contribution to the field by investigating the 700 mb geopotential height associated wiith precipitation and temperature anomalies in Saudi Arabia, it is limited to one upper level, namely 700 mb geopotential height. Therefore this study is a new contribution that reveals the surface pressure, the 500 mb geopotential height, and 200 mb geopotential height patterns and anomalies for the Saudi Arabia and the surrounding regions during thunderstorms in the central part of Saudi Arabia as well as during the third day before thunderstorm in that region.

The Research Problem and its Importance

Thunderstorms are important as a climatological phenomenon in the central part of Saudi Arabia. They have impact on human life, natural system and the socioeconomical sectors in the central part of Saudi Arabia. They bring most of the rainfall for that region, especially in March and April, which are the rainiest two months in the central part of Saudi Arabia. However, sometimes they come with their negative impact that is represented by flashflood, hail, strong wind which from time to time cause destructive effect to many aspects for that region. For instance, on March 21, 1995 a severe thunderstorm that was associated with very heavy rainfall, large size hail, and strong downdraft wind attacked Riyadh killing many people and causing severe damage to thousands of vehicles and buildings. Is is well known that the local heating of the surface and the availability of sufficient moist air at the surface are necessary to the development of most thunderstorms (Oliver and Hidore, 1984). However, synoptic scale pattern and upper level pressure patterns play an important role in the development of thunderstorms in some places (Wallace and Hobbs, 1977). The literature review reveals that there is no research about thunderstorms in Saudi Arabia that provides understanding of the upper level pressure synoptic pattern associated with the development of thunderstorm in the central part of Saudi Arabia. Hence, the main goal of this research is to provide more understanding of the surface and upper level synoptic pattern that might be associated with and precedes thunderstorm event in the central part of Saudi Arabia. Also, the uniqueness of this study stems from other different points from which the following points can be mentioned:

1 - It links the local thunderstorms in the central part of Saudi Arabia to North-

ern Hemisphere synoptic pattern utilizing unique grided upper level data.

2 - It investigates the surface and upper level anomaly patterns for the studied area and the surrounding regions.

3 - It does not only cover the studied region, but also the surrounding region which provides better understanding of the synoptic pattern and anomalies associated with thunderstorms in the central part of Saudi Arabia.

4 - It helps to improve the three-day forecast for thunderstorms in the central part of Saudi Arabia through studying the synoptic pattern three days before the thunderstorm event.

5 - It utilizes one of the Geographical Information System (GIS) programs that enabled drawing accurate contour maps for a huge number of data giving clear picture for the synoptic pattern and anomalies. Without utilizing this technique, it would be very difficult to represent the data in maps with acceptable accuracy that gives the right shape and pattern for the synoptic pattern and anomalies.

Research Data and Methodology

Research Data

Investigations of the precipitation record in the central part of Saudi Arabia indicate that most of the precipitation is due to thunderstorms, especially in March and April.

Therefore, this study utilizes Riyadh's March and April precipitation data to investigate the surface pressure and the 500 mb geopotential height patterns and anomalies associated with thunderstorms in the central part of the country. Riyadh was selected to represent the central part of Saudi Arabia because it has sufficient record of surface data and because it is located in the central part of the country. Daily thunderstorm data for Riyadh were obtained from the Meteorology and Environmental Protection Administration (MEPA) in Saudi Arabia. Daily Surface pressure data, the 500 mb geopotential height data, and 200 mb geopotential height data utilized in this study were obtained from the US National Meteorological Center (NMC) CD-ROM data set. The CD-ROM disc includes a selected subset of the NMC Northern Hemisphere octagonal grid data (National Center for Atmospheric Research, 1990). The data in this disc are for pressure, temperature, wind (U and V component), and height for different levels. The 12Z (12 GMT) observations were used in this study since the investigations indicate that there were no significant differences between the mean pattern of 00Z observations and 12Z observations. The NMC octagonal grid in 1977 points appear as 47 by 51 grid points equally spaced when viewed on a polar stereographic grid (Figure 1). In this research, the areal coverage used during the analyses of the surface pressure and upper level geopotential heights covers an area bounded by 10 N to 90 N and 90 W to 90 E. The goal of this areal coverage is to investigate the surface and upper level pressure patterns and anomalies for Saudi Arabia as well as for the surrounding regions during the occurrence of thunderstorms in the central part of Saudi Arabia.

Methodology

Composite technique was utilized to investigate the surface pressure, the 500 mb geopotential height, and 200 mb geopotential height patterns and anomalies during thunderstorm event as well as during the third day preceding thunderstorms event in Riyadh. There are numerous studies, such as those of Harrington and Harman (1985), Achton and Horn (1986), Yarnal and Diaz (1986), Winkler (1988), and Meischner et al (1997) that have employed composites techniques in meteorological and climatological studies. Composite technique is the selection of data, which represent number of events which satisfies an important criterion, then average them in on map (Yearnal, 1993). This means that the map presented exhibits the pattern during specified events. In the analyses of this study, the upper data were classified by surface environment-based criteria. In this approach, the criteria for separating the synoptic classes were based on the environmental variables. The surface environmental criterion used in this study is the thunderstorm event in Riyadh, which represents the central part of Saudi Arabia. This approach is called environmental-to-circultion classification (Yarnal, 1993). The purpose of applaying this study is to investigate the pattern and anomalies of the surface pressure and 500 mb and 200 mb geopotential height associated with thunderstorms in the central part of Saudi Arabia.

This study covers only two months, Mrach and April. This decision is based on the fact that thounderstorms and associated rainfall are more frequent in these two months in the central part of Suadi Arabia (Figure 2). Because the data temporal coverage in the available NMC CD-Rom disc extends only up to 1989, the period covered in this research is between 1972 and 1989. However, investigation of the data indicates that this period of time contains enough thunderstorm events. The methodology of this research can be summarized in the following points:

First, the averages of the surface pressure, the 500 mb geopotential height, and 200 mb geopotential height for March and April for the covered area were extracted from the NMC CD-Rom disc and mapped to represent the normal patterns for the studied period, 1972 to 1989.

The technique used to extract the maps from the CD-ROM disc and draw the maps is as follows:

A - Base map was created to cover exactly the studied area, which is bounded by 10° N to 90° N and 90° W to 90° E.

B - A FORTRAN program was written to extract the needed data from a huge number of different data in the CR-ROM disc.

C - The extracted data were then transferred to SURFER, one of the GIS programs, to be gridded, blanked, contoured, smoothed, and mapped as contour lines over the base map for the studied area. Gridding means putting the composted value exactly in the same longitude and latitude point that represents the geographical location of the composted value.

Blanking means blanking the contour lines that extend outside the borders of the base map for the covered area. Contouring means connecting the grid points that have the same composted values based on selected intervals. Smoothing is making the contour lines appear as smooth lines as much as possible without affecting the accuracy of the representation of the contour lines.

Second, the days for the strongest seven thunderstorms in record for March and April for the covered period were defined (Table 1). The rainfall quantity associated with the thounderstorm was used as a measure of the strength of the thounderstorm. Afterward, the surface pressure, the 500 mb geopotential height, and 200 mb geopotential height patterns for these days were extracted from the NMC CD-ROM disc, composted, and mapped using the same GIS technique mentioned in the previous section. The purpose of this step was to examine the surface pressure, the upper level geopotential height patterns over Saudi Arabia.

Third, the surface pressure and upper level geopotential heights during the third day prior to the thunderstorm day were also investigated. This was done to determine if there were any well-defined surface pressures and 500 mb and 200 mb geopotential heights preceding the thunderstorm days. The existence of such patterns can be a reliable basis for thunderstorm forecasts for the central part of Saudi Arabia.

Fourth, the surface pressures, the 500 mb geopotential height, and 200 mb geopotential height anomalies during thunderstorm days were calculated and mapped. This was done by subtracting the values of the normal pattern from the composite pattern.

In the 500 mb and 200 mb geopotential height pattern maps, the 5810 geopotential meter and 12220 geopotential meter height contours were chosen as reference lines to show the southward advance or the northward retreat of the 500 mb geopotential height and 200 mb geopotential height contours as well as the associated trough and ridge systems.

All the above steps are essential to explain the nature of the existing systematic patterns and anomalies for the covered area, such as wave patterns and strong ridge-trough patterns, during thunderstorm days in the central part of the country and the third day prior to the thunderstorm event.

Table (1). The dates of occurrence for the studied thunderstorms and the quantity of the precipitation for each thunderstorm event.

Month					
March			April		
Thunder-storm	Date of Occurrence	Precipitation Quantity (mm)	Thunder-storm	Date of Occurrence	Precipitation Quantity (mm)
1	3-22-1972	52	1	4-08-1971	57
2	3-29-1975	32	2	4-24-1972	29
3	3-20-1976	23	3	4-12-1975	15
4	3-26-1982	17	4	4-04-1976	37
5	3-20-1984	22	5	4-03-1983	13
6	3-05-1986	17	6	4-25-1986	30
7	3-28-1989	29	7	4-24-1988	14

Results

Surface Pressure Pattern and Anomalies

The main feature of March normal surface pressure pattern for the studied period (Figure 3A) is the existence of three centers of surface pressure systems. These centers are the Icelandic low pressure, the subtropical Azores high pressure and the Siberian high pressure. The normal surface pressures for the desert region extending from North Africa to Saudi Arabia is characterized by below 1013 mb weak pressure gradient. Apparent intensification of the Icelandic low-pressure system and development of more meridional patterns characterize the pattern during the third day before thunderstorm day (Figure 3B) over North Africa and Arabian peninsula. During the thunderstorm days (Figure 3C), the meridional pattern deepens which causes the Icelandic low to extend southwestward creating an obvious low pressure center over northeastern North America. Over Saudi Arabia, the surface pressure became much lower than the normal pattern with intensification and expansion northward of the Red Sea surface low pressure. With respect to the surface pressure anomaly patterns during thunderstorm day in Riyadh in March (Figure 3D), there is obvious domination of negative anomalies. The strongest centers of negative anomalies are in the Icelandic low area and Northwestern Africa. Saudi Arabia has a center of negative anomaly but not as strong.

For April (Figure 4A to 4D), the normal pattern indicates that the icelandic low pressure system mentioned in March pattern is much weaker with another high pressure system developed over northern Greenland and Canada. However, the Azure high pressure intensified. The pressure gradient over North Africa and the Arabian Peninsula is stronger than that of March with lower pressure values. During the third day before thunderstorm day, the pressurre systems started to take meridional formation. During the thunderstorm day the meridional pattern intensified showing standing waves extending from the Atlantic Ocean to Arabian peninsula causing strengthening and northern advancement of the Red Sea surface pressure system. This causes the development of surface trough just west of the country. However, the surface high pressures over central Asia weaken. The anomaly pattern for April is similar to that of March but the anomaly values are much lower.

500 mb Geopotential Height Pattern and Anomaly

There is similarity between the normal pattern of March and April (Figure 5A and 6A), but the height gradient in April is weaker. Also, there is similarity between the composite patterns of March and April (Figure 5B, 5C, 6B and 6C). The 500 mb geopotential heights during the third day before thunderstorm in both months show the development of a wave pattern over the Atlantic and northwestern Afrian. During the thunderstorm day the wave pattern strentghened and extended eastward with series of trough-ridge pattern extending to Saudi Arabia. These trough-ridge series are troughs over mid-Atlantic Ocean, northwestern Africa, and over the Red Sea just west of Saudi Arabia and the ridges are over eastern Atlantic and central north Africa. This wave pattern puts Saudi Arabia under cyclogensis effect. Meteorologically, area of cyclogenesis in charachterized by convergence at surface and divergence in the upper levels that enhance the instability.

March 500 mb geopotential height anomaly patterns during thunderstorm day (Figure 5D were characterized by strong centers of positive and negative anomalies. The locations of these centers correspond to the location of the trough-ridge that appeared in the 500 mb geopotential height pattern during thunderstorm day. North Atlantic ocean, northwestern Africa, and the eastern Mediterranean are dominated by strong negative anomaly, but there is a tongue of pronounced positive anomalies extending northward from the central part of north Africa to the central part of the Mediterranean and Europe. The pattern reflects the strength of the two troughs over Northwestern Africa and the Red Sea and the ridge between the two troughs. Northeastern of North America has strong center of positive anomaly. In April, the 500 mb geopotential height anomalies pattern during thunderstorm day (Figure 6D) over the area extending from Northwestern Africa to the Mediterranean and the Arabian Peninsula is almost similar to that of March. However, the pattern over the rest of the covered area is different. In contrast to March anomaly pattern, central Atlantic Ocean has pronounced center of positive anomalies and eastern North America has center of negative anomalies. The center of positive anomaly over central Atlantic Ocean extends northeastern to connect with the positive anomalies over central and eastern Europe.

200 mb Pattern and Anomaly

As expected, the 200 mb geopotential height anomaly pattern for the studied period exhibits pronounced zonal pattern in both March and April (Figure 7A and Figure 8A). However, the pattern over central and Eastern Europe shows an upper trough with weak height gradient. During the third day before thunderstorm (Figure 7B and 8B), the height gradient starts to take more meridional pattern. This meridional pattern is more obvious during the storm day in both months (Figure 7C and 8C). This is represented by trough-ridge formation almost similar to that observed in the 500 mb geopotential height pattern. The pressure gradient over Saudi Arabia during the thunderstorm day in March and April is tighter than the normal pattern. This is indicative of stronger jet stream velocity. High jet stream velocity enhances the uplifiting, and consequently increases instability. However, the anomaly of wind velocity in the 200 mb height need to be investigated to determine the strength of the jet stream over the studied area during thunderstorms in the central part of Saudi Arabia.

Similarly, the 200 mb geopotential height anomaly pattern for the covered area during the thunderstorm day in Riyadh for March and April (Figure 7D and 8D) coincides with that of 500 mb geopotential height. This is indicative of the strength of the upper pattern during thunderstorm days in the central part of Saudi Arabia, which clearly extends vertically to upper levels.

Conclusion

This research has revealed many important findings about surface pressure, 500 mb, and 200 mb geopotential height patterns and anomalies associated with thunderstorm events in the central part of Saudi Arabia and during the third day before.

The surface pressure pattern for the studied area during thunderstorm day in the central part of the Saudi Arabia is characterized by obvious intensification of the icelandic low pressure system and development of more meridional patterns over north Africa and Arabian Peninsula. This is associated with intensification and extension northward of the Red Sea surface low pressure. The surface pattern emphasizes the role of the Red-Sea surface low pressure in the development of thunderstorms in this part of Saudi Arabia. The northward advancement of the intensified Red-Sea low pressure is associated wih southerly wind that provides the needed moisture to the development of thunderstorms in the central part of Saudi Arabia.

The 500 mb and 200 mb geopotential heights patterns and anomalies during thunderstorm in Riyadh and during the third day before reveal important findings. When pronounced upper level trough development over Northwestern Africa with pronounced ridge develops over the central and western Mediterranean, there could be upper level trough just west of Saudi Arabia. When the trough is located just west of Saudi Arabia, putting most of the country under an area of cyclonic activity, the central part of Saudi Arabia experiences thunderstorm. Also, the development of thunderstorm over the central part of Saudi Arabia is associated with the development of ridge over western Atlantic Ocean and eastern North America. This indicates that thunderstorms development over the central part of Saudi Arabia is preceded by the progression of trough-ridge pattern from western Mediterranean to the Arabian Peninsula. The progression of the Mediterranean trough is caused by the circulation pattern over the eastern Atlantic and Western Europe (Alkolibi, 1995). When the Mediterranean trough reaches estern Mediterranean region, it then becomes aligned with the trough over Europe and the Red Sea trough creating a deep long wave trough extending to Saudi Arabia. These findings support the result of previous research that concluded that the 700 mb geopotential height patterns and anomalies during precipitation in Saudi Arabia and during the third day before are characterized by the progression of the Mediterranean trough from central north Africa to the Arabian peninsula (Alkolibi, 1995).

The 500 mb and 200 mb geopotential height anomalies for the covered area during March and April thunderstorms in the central part of Saudi Arabia have well defind patterns. When the area extending from western Atlantic Ocean to the Arabian Peninsula is dominated by negative (below normal) 500 and 200 geopotential height anomalies, thunderstorms develop in the central part of Saudi Arabia. Kerr, 1988, found that cold events (La Nina events) are characterized by below normal surface temperatures and below normal geopotential heights in the Northern Hemisphere. This suggests that March and April thunderstorm in the central part of Saudi Arabia may be related to cold events.

It is obvious from the finding of this research that thunderstorm event in the central part of Saudi Arabia is not only due to a local thermodynamic effect but also comes with active synoptic system that can be observed in Surface pressure as well as different upper levels.

This synoptic pattern occurs when meridional pattern dominates the area extending eastward from North America to central Asia with pronounced wave pattern progressing eastward. During the thunderstorm event day, a deep trough becomes located just west of the country. The combination of strong Red Sea surface low pressure and this upper level trough provides the needed ingredient for the development of thunderstorms in the central part of Saudi Arabia. The surface pressure causes moist southerly wind providing the needed moisture and the upper level pattern provides the lifting mechanism, upper level cooling, and strong jet stream which are the needed factors to intensify the instability. Nevertheless, thermodynamic effect can not be ignored in such region during these two months, but need to be investigated.

Based on the findings of this research it is essential to carefully monitor the upper atmospheric patterns over the eastern Atlantic Ocean, the western Mediterranean, and Europe to improve the thunderstorms forecasts in the central part of Saudi Arabia. Also, it is important to investigate the relationship between the climate of Saudi Arabia and other indices that are important to these regions, such as the North Atlantic Oscillation Index (NAOI). The findings of this research provide a better understanding of the effect of the upper atmospheric pressure and circulation on the climate of Saudi Arabia. Also it provides better understanding of the synoptic pattern responsible for thunderstorms occurrence in the central part of the country.

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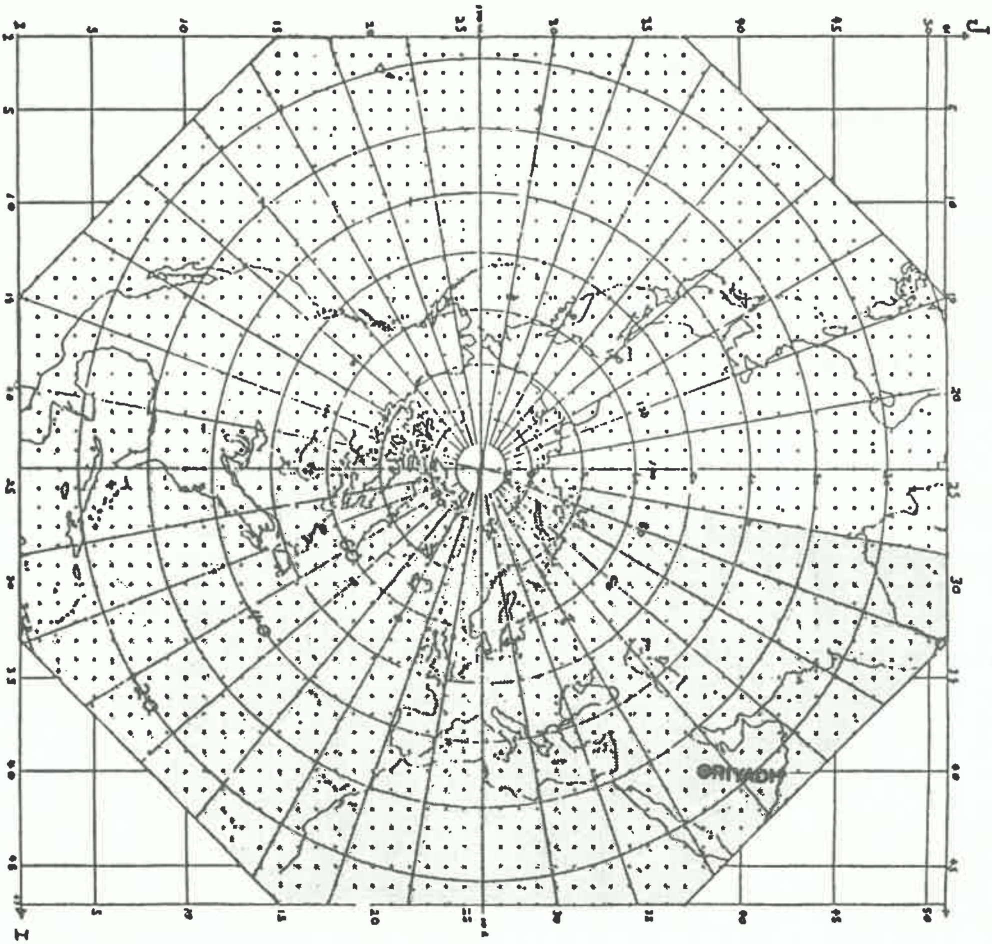

Figure 1. NMC 47x51 octagonal grid and the location of the surface station (Riyadh). The shaded area represents the grid points covered in this study.

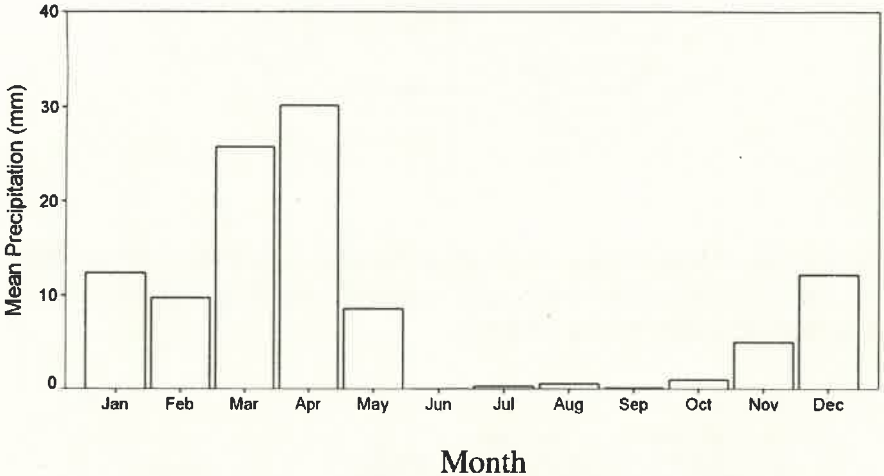

Figure 2. Riyadh's Monthly mean Precipitation for the period between 1961 and 1995.

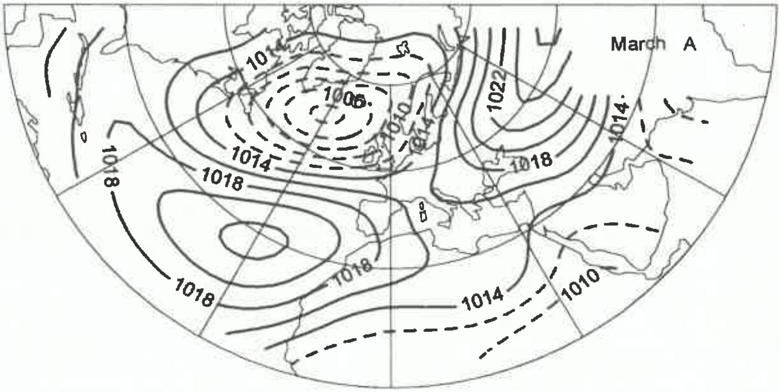

Figure 3.A. March average (normal) surface pressure from 1972 to 1989 for Saudi Arabia and the surrounding regions. The dashed contours represent presuure values below 1014 mb.

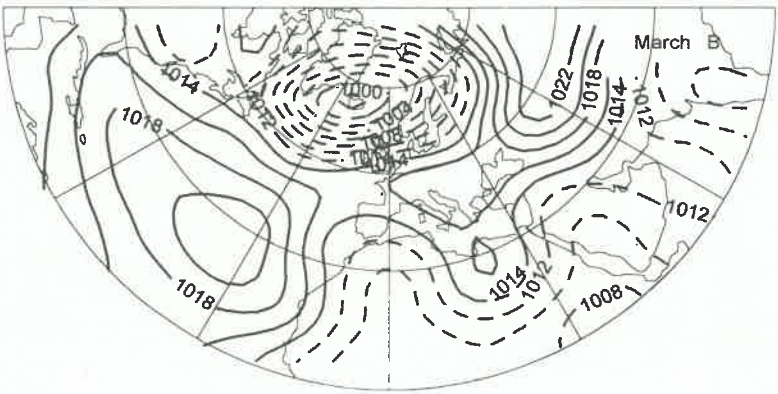

Figure 3.B. March surface pressure composite for Saudi Arabia and the surrounding regions during the third day before the thunderstorm event in the central part of Saudi Arabia. The dashed contours represent pressure values below 1014 mb.

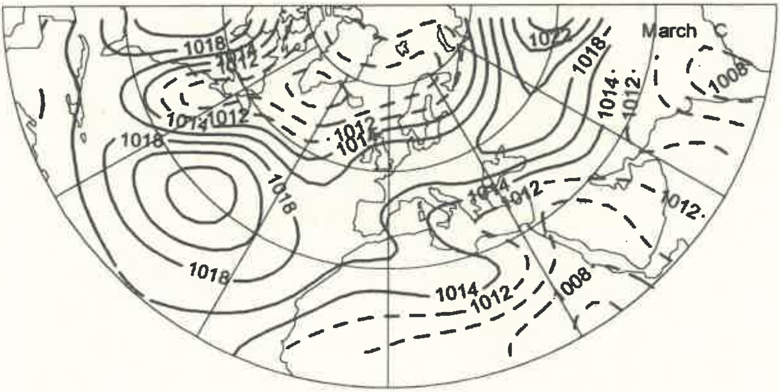

Figure 3.C. As in Figure 3.B, but during the thunderstorm event in the central part of Saudi Arabia.

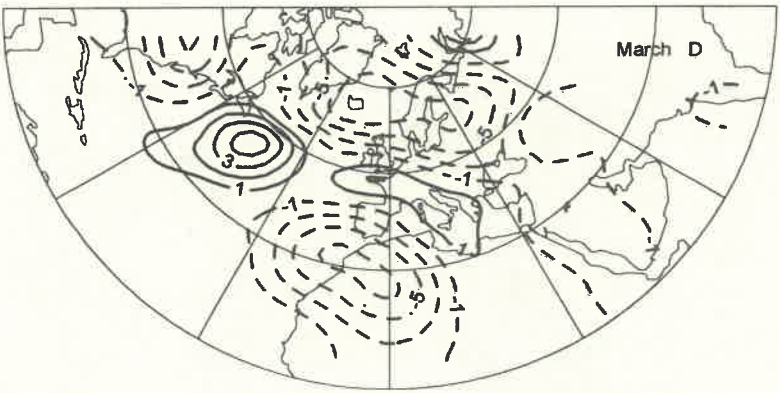

Figure 3.D. March anomaly chart for surface pressure pattern during thunderstorm event in the central part of Saudi Arabia obtained by subtracting the normal pattern values from those during thunderstorm event in the central part of Saudi Arabia. Negative anomalies are shown by dashed contours, positive anomalies are shown by solid contours, the contours are at a 2 mb interval.

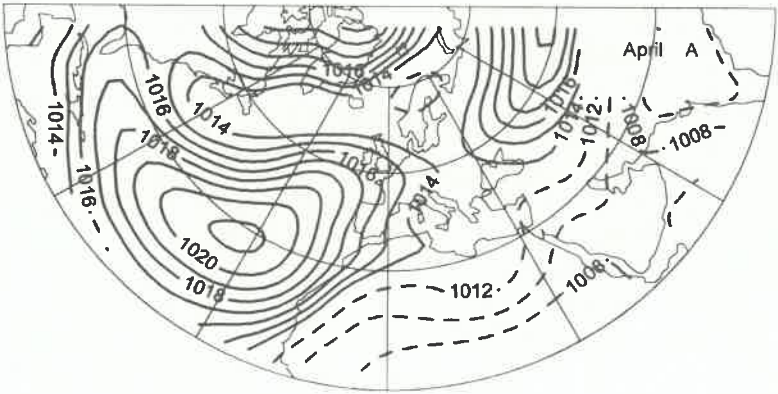

Figure 4.A. April average (normal) surface pressure from 1972 to 1989 for Saudi Arabia and the surrounding regions. The dashed contours represent pressure values below 1014 mb.

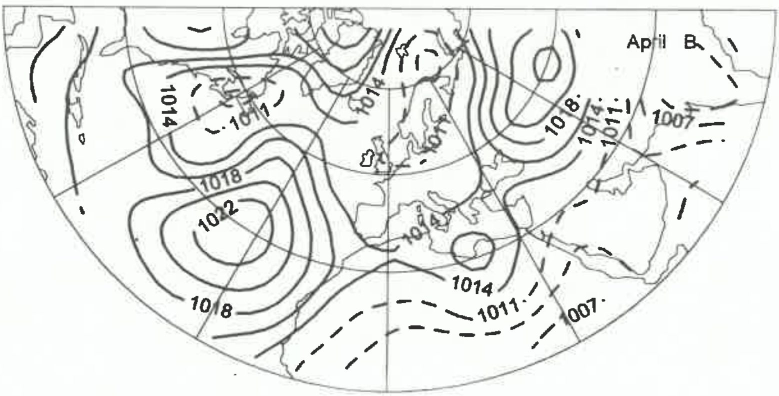

Figure 4.B. April surface pressure composite for Saudi Arabia and the surrounding regions for the third day before the thunderstorm event in the central part of Saudi Arabia. The dashed contours represent pressure values below 1014 mb.

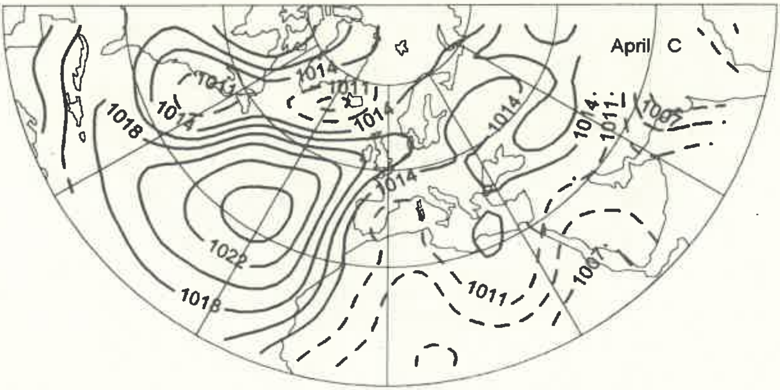

Figure 4.C. As in Figure 4B, but during the thunderstorm event in the central part of Saudi Arabia. The dashed contours represent pressure values below 1014 mb.

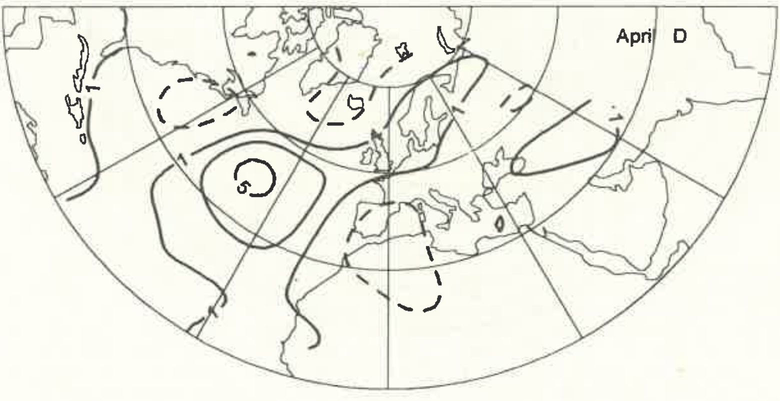

Figure 4.D. April anomaly chart for surface pressure pattern during thunderstorm event in the central part of Saudi Arabia obtained by subtracting the normal pattern values from those during thunderstorm event in the central part of Saudi Arabia. Negative anomalies are shown by dashed contours, positive anomalies are shown by solid contours, the contours are at a 2 mb interval.

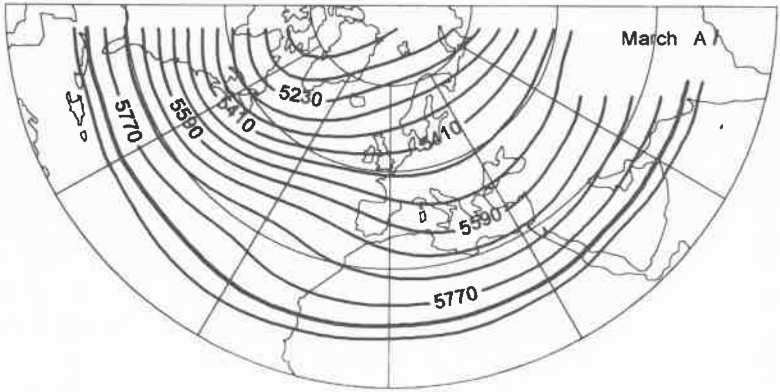

Figure 5.A. March average (normal) 500 mb geopotential height from 1972 to 1989 for Saudi Arabia and the surrounding regions. The contours are at 60g pm and the bold solid contour represents the reference contour line.

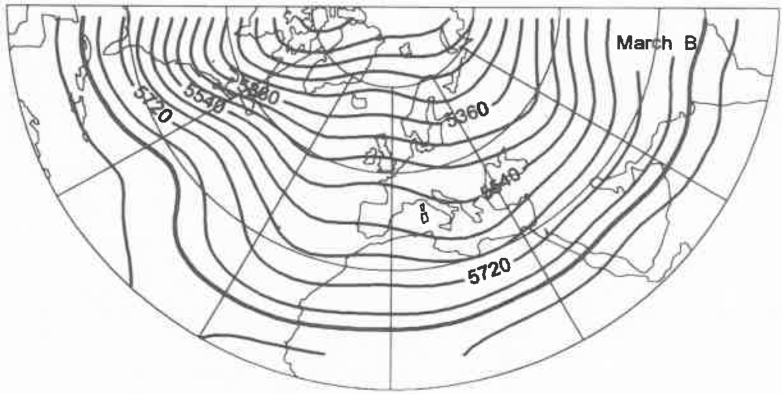

Figure 5.B. March 500 mb geopotential height composite pattern for Saudi Arabia and the surrounding regions for the third day before the thunderstorm event in the central part of Saudi Arabia. The contours are at 60g pm and the bold solid contour represents the reference contour line.

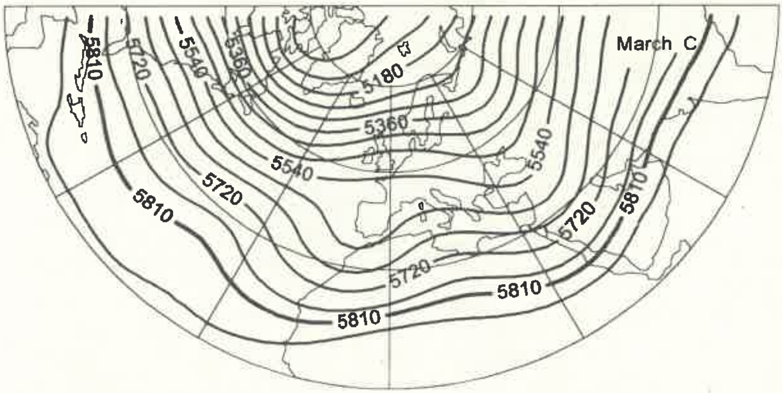

Figure 5.C. As in Figure 5B, but during the thunderstorm event in the central part of Saudi Arabia. The contours are at 60g pm.

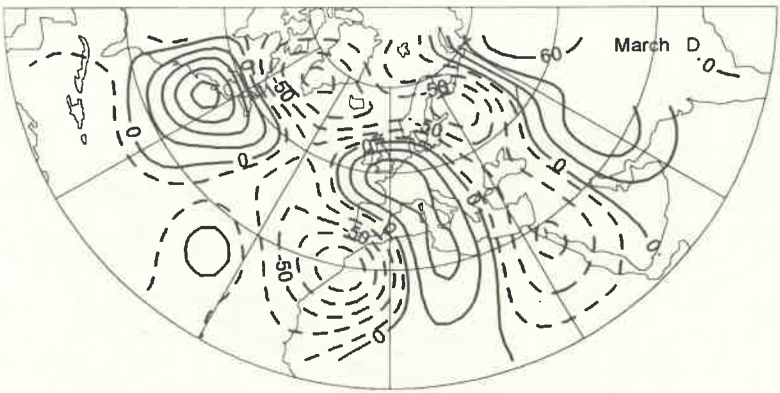

Figure 5.D. March 500 mb geopotential height anomaly pattern during thunderstorm event in the central part of Saudi Arabia obtained by subtracting the normal pattern values from those during thunderstorm event in the central part of Saudi Arabia. Anomalies <0g pm are shown by dashed contours, anomalies >0g pm are shown by solid contours, the contours are at a 20g pm interval.

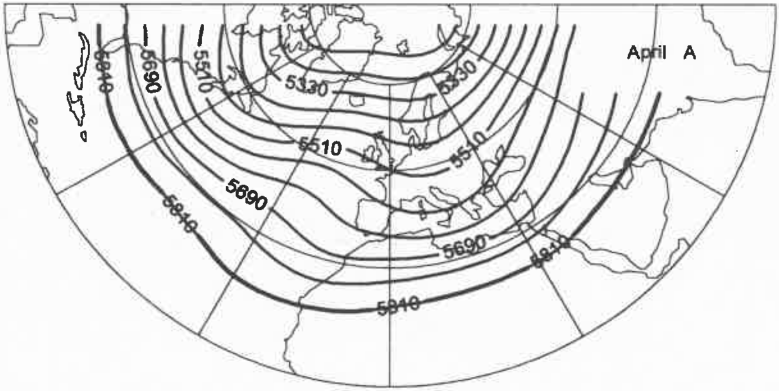

Figure 6.A. April average (normal) 500 mb geopotential height from 1972 to 1989 for Saudi Arabia and the surrounding regions. The contours are at 60g pm and the bold solid contour represents the reference contour line.

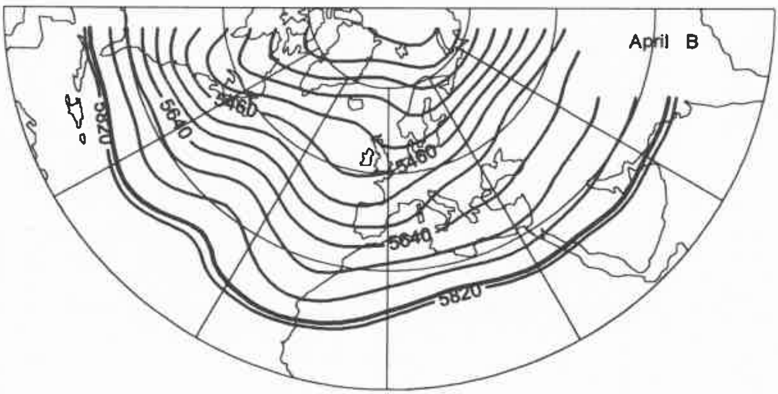

Figure 6.B. April 500 mb geopotential height composite for Saudi Arabia and the surrounding regions for the third day before the thunderstorm event in the central part of Saudi Arabia. The contours are at 60g pm and the bold solid contour represents the reference contour line.

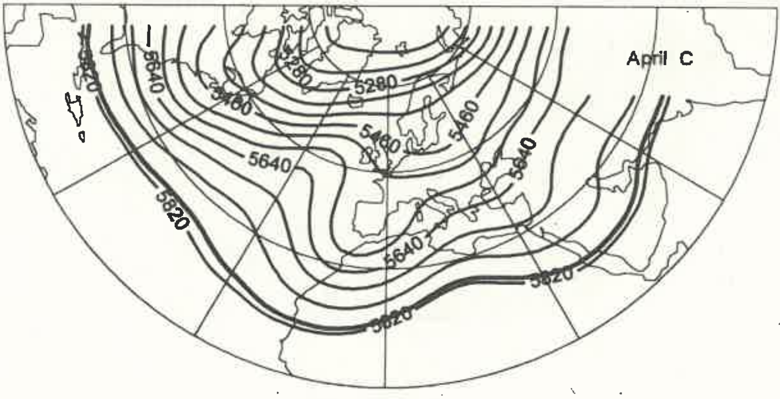

Figure 6.C. As in Figure 6B, but during the thunderstorm event in the central part of Saudi Arabia. The contours are at 60g pm.

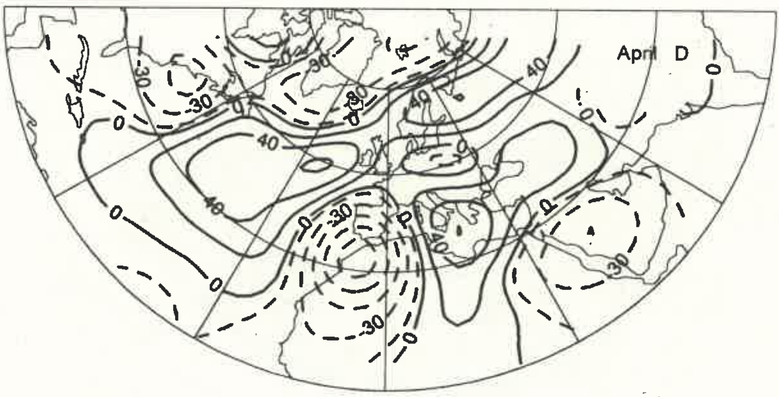

Figure 6.D. April 500 mb geopotential height anomaly pattern during thunderstorm event in the central part of Saudi Arabia obtained by subtracting the normal pattern values from those during thunderstorm event in the central part of Saudi Arabia. Anomalies <0g pm are shown by dashed contours, anomalies >0g pm are shown by solid sontours, the contours are at a 20g pm interval.

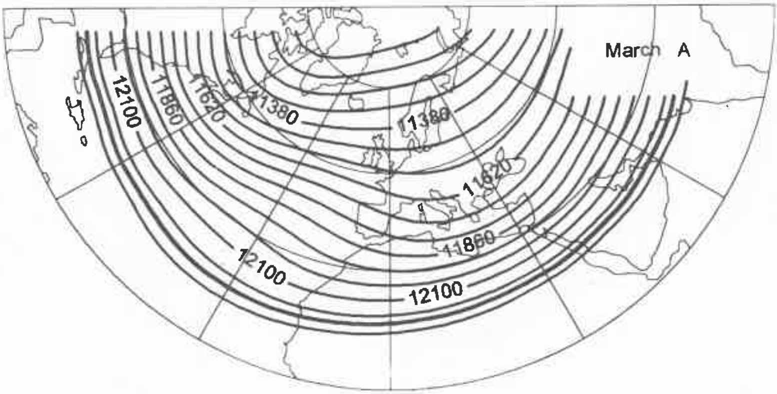

Figure 7.A. March average (normal) 200 mb geopotential height from 1972 to 1989 for Saudi Arabia and the surrounding regions. The contours are at 80g pm and the bold solid contour represents the reference contour line.

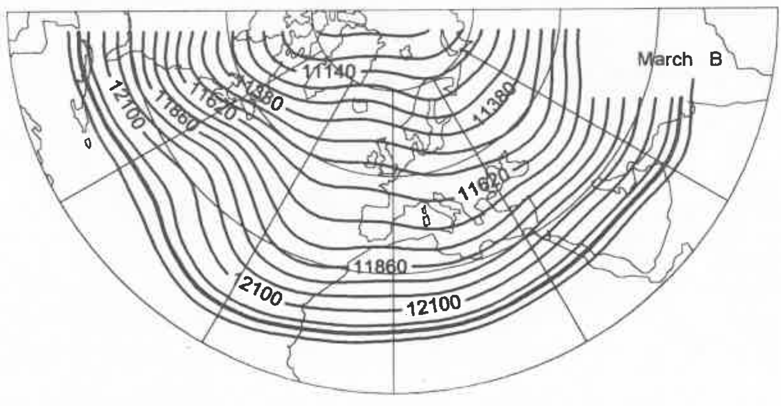

Figure 7.B. March 200 mb geopotential height composite pattern for Saudi Arabia and the surrounding regions for the third day before the thunderstorm event in the central part of Saudi Arabia. The contours are at 80g pm and the bold solid contour represents the reference contour line.

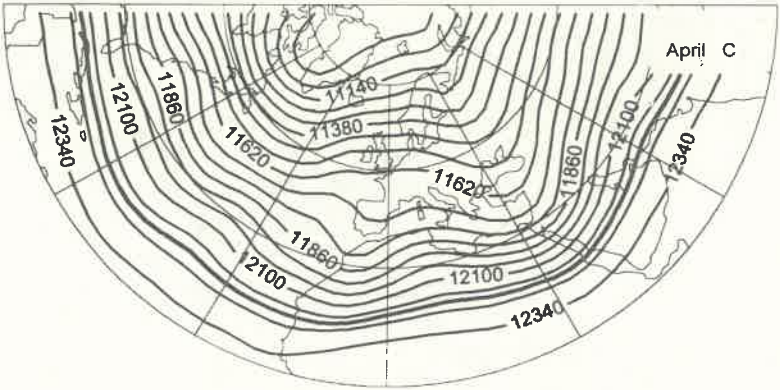

Figure 7.C. As in Figure 7B, but during the thunderstorm event in the central part of Saudi Arabia. The contours are at 80g pm.

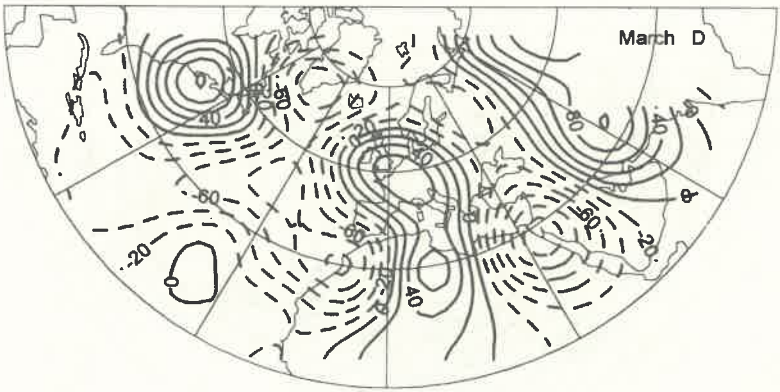

Figure 7.D. March 200 mb geopotential height anomaly pattern during thunderstorm event in the central part of Saudi Arabia obtained by subtracting the normal pattern values from those during thunderstorm event in the central part of Saudi Arabia. Anomalies <0g pm are shown by dashed contours. anomalies >0g pm are shown by solid contours, the contours are at a 20g pm interval.

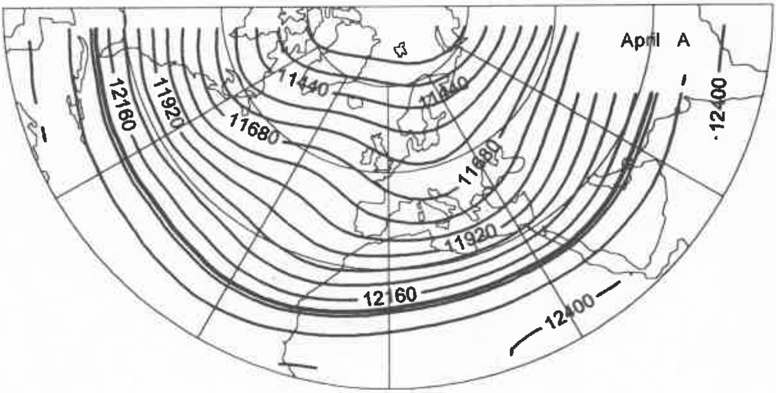

Figure 8.A. April average (normal) 200 mb geopotential height from 1972 to 1989 for Saudi Arabia and the surrounding regions. The contours are at 80g pm and the bold solid contour represents the reference contour line.

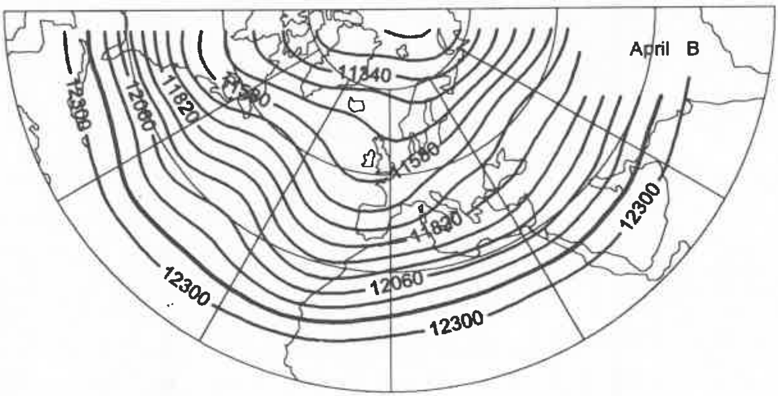

Figure 8.B. April 200 mb geopotential height composite pattern for Saudi Arabia and the surrounding regions for the third day before the thunderstorm event in the central part of Saudi Arabia. The contours are at 80g pm and the bold solid contour represents the reference contour line.

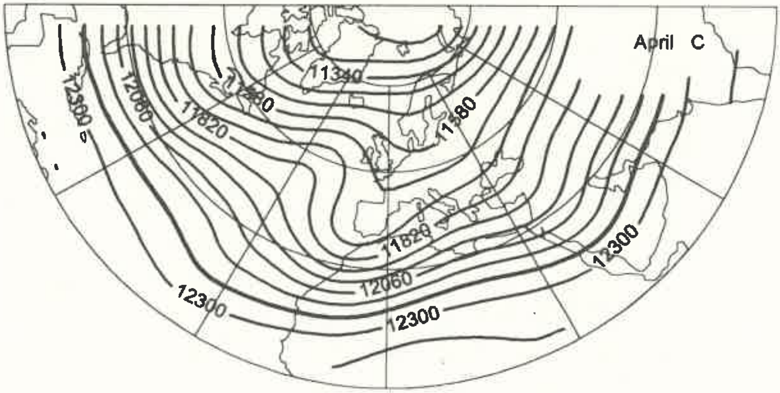

Figure 8.C. As in Figure 8B, but during the thunderstorm event in the central part of Saudi Arabia. The contours are at 80g pm.

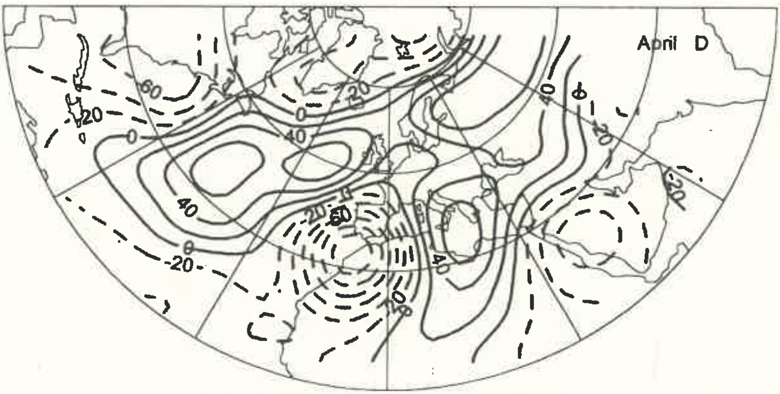

Figure 8.D. April 200 mb geopotential height anomaly pattern during thunderstorm event in the central part of Saudi Arabia obtained by subtracting the normal pattern values from those during thunderstorm event in the central part of Saudi Arabia. Anomalies <0g pm are shown by dashed contours, anomalies >0g pm are shown by solid contours, the contours are at a 20g pm interval.

tem) واضح المعالم ويمكن متابعته أفقيا في مناطق محيطة بمنطقة الدراسة وهو أيضا عميق ويمتد إلى وسط وأعلى طبقة التروبوسفير (Mid. and Upper the Troposphere Layer) ، ويمكن تلخيص معالم ذلك النمط على النحو التالي :

ثلاثة أيام قبل حدوث العاصفة الرعدية في وسط المملكة العربية السعودية يبدأ نمط طولاني (Meridional Pattern) واضح في ارتفاعات مستوى ٥٠٠mb و٢٠٠mb بالنشوء في المنطقة الممتدة من وسط أمريكا الشمالية إلى وسط آسيا ويصاحب ذلك موجات في طبقات الجو العليا تتقدم من الغرب للشرق ، في يوم العاصفة الرعدية على وسط المملكة تتعمق هذه الموجات وتزداد طولانيتها فيصبح غرب المملكة العربية السعودية واقعا تحت أخدود هوائي عميق (Deep Trouph) يمتد حتى طبقة ٢٠٠mb مما يجعل وسط المملكة يقع تحت تأثير نمط إعصاري (Cyclogensis Pattern) ويصاحب ذلك نشاط ملحوظ لمنخفض البحر الأحمر وتقدمه شمالا . تضافر هذين النظامين يوفر المركبات الأساسية لنشوء العواصف الرعدية وسط المملكة العربية السعودية ، فالأخدود الهوائي العميق في طبقات الجو العليا يوفر التبريد العلوي اللازم وديناميكية الرفع المطلوبة (Dynamic Lifting) ، أما منخفض البحر الأحمر فيوفر رياحا سطحية جنوبية رطبة ، كل هذا يؤدي إلى نشوء حالة عدم استقرار جوي على وسط المملكة وبالتالي نشوء العواصف الرعدية على تلك المنطقة .

هذه النتائج تشير إلى أهمية مراقبة ومتابعة التغيرات الطقسية اليومية في وسط وأعلى طبقة التروبوسفير فوق المناطق الواقعة غرب المملكة وبالذات شرق المحيط الأطلسي وغرب أوروبا لأن ذلك سوف يخدم وبشكل كبير توقع حدوث العواصف الرعدية على وسط المملكة العربية السعودية .

ABSTRACT

أنماط الضغط الجوي السطحي وارتفاعات ٥٠٠ mb و ٢٠٠ mb المصاحبة للعواصف الرعدية في وسط المملكة العربية السعودية

د. فهد محمد الكليبي *

في هذا البحث تمت دراسة أنماط الضغط السطحي وارتفاعات طبقتي ٥٠٠ mb و٢٠٠ mb فوق المملكة العربية السعودية ومناطق واسعة محيطة بها والمتزامنة مع حدوث العواصف الرعدية وثلاثة أيام قبل حدوثها في وسط المملكة العربية السعودية ، كما تم أيضا فحص أنماط الشذوذ (Anomalies) في المستويات السالفة الذكر والمتزامنة مع حدوث العواصف الرعدية في وسط المملكة العربية السعودية ، وقد تم ذلك بواسطة تطبيق أسلوب تحليل المركبات (Composite Analysis) وأساليب إحصائية أخرى واستخدام أحد برامج نظم المعلومات الجغرافية (GIS) .

المعلومات السطحية التي تم استخدامها في هذا البحث هي معلومات يومية للعواصف الرعدية لمدينة الرياض والتي تمثل وسط المملكة العربية السعودية لشهري مارس وأبريل ، أما معلومات الضغط السطحي والمعلومات العلوية التي تمثل ارتفاعات طبقتي ٥٠٠ mb و٢٠٠ mb فهي معلومات يومية لمنطقة واسعة في نصف الكرة الشمالي محصورة ما بين ١٠ ـ ٩٠ شمالا ، و٩٠ غربا ، إلى ٩٠ شرقا ، الغرض من تغطية تلك المنطقة الواسعة هو دراسة أنماط الارتفاعات والشذوذ في المستويات السابقة الذكر المصاحبة والسابقة للعواصف الرعدية ليس فقط فوق منطقة الدراسة بل أيضا فوق المناطق المحيطة بها لفهم العلاقة بين ما يحدث في أسفل ووسط وأعلى طبقة التروبوسفير في تلك المناطق الواسعة وحدوث العواصف الرعدية في وسط المملكة العربية السعودية .

نتائج هذه الدراسة تشير إلى أن العواصف الرعدية في وسط المملكة في شهري مارس وأبريل لا تحدث فقط بسبب ظروف محلية ولكن أيضا تأتي مع نظام سينبتيكي (Synoptic Sys-

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