Seasonal Distribution of Minimum Temperature over the Kingdom of Saudi Arabia

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ABSTRACT **:** To examine the monthly and spatial variability of the minimum temperature over the Kingdom of Saudi Arabia (KSA), a set of data record of 57 years of monthly minimum temperature was used in this study. Climatologically values of mean minimum temperatures and their spatial variability were illustrated for the different seasons of the year. Then, significant regions in minimum temperature were described using yearly and monthly means minimum temperature. The study revealed the presence of a permanent thermal low of minimum temperature over water area in the Red Sea and thermal high of minimum temperature over land area in Al Rub-Al khali.

Introduction

Temperature is an important parameter in the climatic system and is strongly influenced by many metabolic processes in plants (respiration, photosynthesis, development, etc.) and it is one of the principal environmental factors affecting their growth and yield. Sometimes, temperatures reach a critical level which produces a climatic risk for crops in many agricultural areas. Low air temperatures in many areas of the world result in a significant losses in agricultural production. For example, frost, one of the principal

risks for crops is defined as the lowering of the temperature to a few degrees below 0 °C during periods of the year when plants, owing to their water content, could suffer irreversible damage.

Minimum temperature increased about twice as fast as maximum temperature over global land areas since 1950, resulting in a broad decline in the diurnal temperature range (DTR) (Folland *et al*., 2001). Changes in cloud cover, precipitation, soil moisture, and atmospheric circulation likely accounted for much of the trend differential during this period (Dai *et al*., 1999; Przybylak, 2000; Braganza *et al*., 2004). Changes in land use also impacted the DTR in some areas (e.g., Balling *et al*., 1998; Bonan, 2001; Small *et al*., 2001).

In this work a record of data set of about 57 years was used to describe the distribution of minimum temperatures in KSA and surrounding area in different seasons of the year and compare their distribution and strength with the annual mean of minimum temperature on the whole period of data set.

Data used and Method

The data set used in this study was obtained from the record of the National Centers for Environmental Prediction/National Center for Atmospheric Research - NCEP/NCAR reanalysis project (Kalnay *et al.*, 1996) that covers the period from 1948 to 2004. One of the main advantages of re-analysis data sets is that model parameterizations and resolution are unchanged for the whole time period. Another advantage compared to operational analyses is that assimilated

observations include late observational reports. The spectral horizontal resolution of the numerical model (T62) and the spatial and temporal resolution of the girded data (2.5°x2.5°, available for 00, 06, 12, 18 GMT) do not allow a good coverage of very small and short lived systems, even if they were originally detected by the observational network.

In the present study, the average of the annual minimum temperature for the period from 1948 to 2004 was calculated at each grid point. The average of minimum temperature for each month of the year throughout the whole period available was also calculated.

Results

Mean Minimum Temperature

Fig. 1 shows the distribution of annual mean minimum temperature over the Kingdom of Saudi Arabia (KSA) and the surrounding areas, with high minimum temperatures of about 26^{o}C over all water areas except over the Red sea where it is more than 28^{o}C, i.e., it is greater than the minimum temperature over areas of the Arabian Gulf or the Indian Ocean. The interior continental area of KSA shows a decrease of temperature gradient from the water areas to inside land, with lowest values on the south-west area, and North area of about 18^{o}C and less than 16^{o}C respectively. Fig. 1, also shows that the gradient of minimum temperature on the south east area of KSA is very low compared to the other neighbor-water, and the minimum temperature on the north area is much lower by about 3^{o}C than the southwest area.

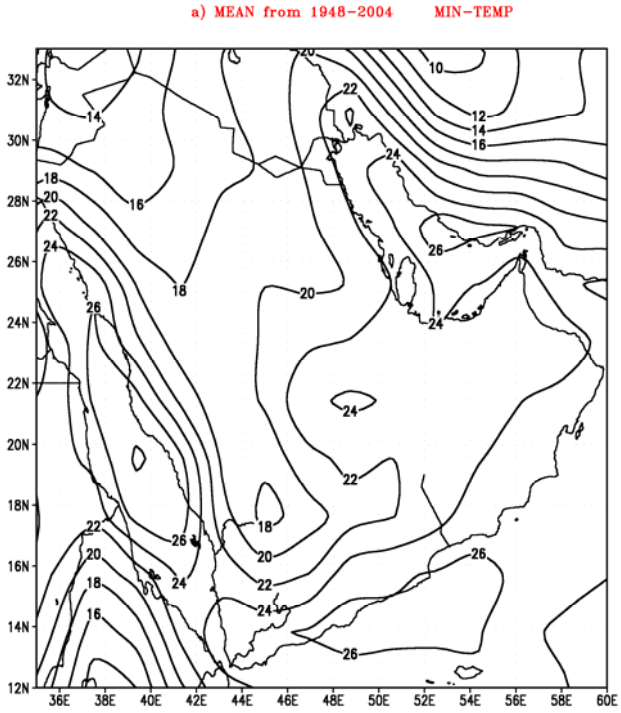

FIG. 1, The average of the annual minimum temperature over the period from 1948 to 2004

In general, the mean minimum temperature pattern over the KSA can be classified into four regions:

1- The neighbor water land region: the region that surrounds KSA from all directions except North.

2- The north region: the boundary of this region is from 25^{o}N to 32.5^{o}N and from 37.5^{o}E to 50^{o}N

3- The southwest region: its boundary is from 15^{o}N to 20^{o}N and from 42.5^{o}E to 47.5^{o}E.

4- The southeast region: its boundary is from 17.5^{o}N to 25^{0}N and from 47.5^{o}E to 57.5^{o}E.

Winter Mean Temperature

In winter months, as shown in Fig. 2, December showed the lowest minimum temperature in this season, where the highest temperature over the Red sea was about 18^{o}C, and reachd -3^{o}C in the north region.

Also, the gradient of temperature between water and inland areas is high around Red sea and low gradient in the southwestern area of the KSA. The classification regions on mean distribution are still recognized in all months of winter season.

The general notice during winter months is the increase of minimum temperature from December to February, with highest minimum temperature in February. The second general feature in the distribution of minimum temperature in winter months is that the shape of isotherms in the interior land form what is called thermal trough in parallel to the Red Sea from north to south boundary of KSA. Also, the isotherms form what is called thermal ridge which is extended from south-east to north-west of the KSA. It is clear that the gradient of minimum temperature in the interior land is concentrated in the northern part of the KSA, with very low gradient in the southeast part.

The difference between the winter months mean and the annual mean is shown in Fig. 3. Two land areas of highest difference are found: One over the northern part of the KSA and the other in the south-eastern part, Al-Rub Al-Khali, but with relative low value than the first one. The difference decreased from December to February,

although the two high difference areas were still recognized on all months.

The interesting point is that, the difference in the Arabian Gulf has greater value than that in the Red-Sea in all months, as if the minimum temperature of the Red-Sea water is more stable and less changing.

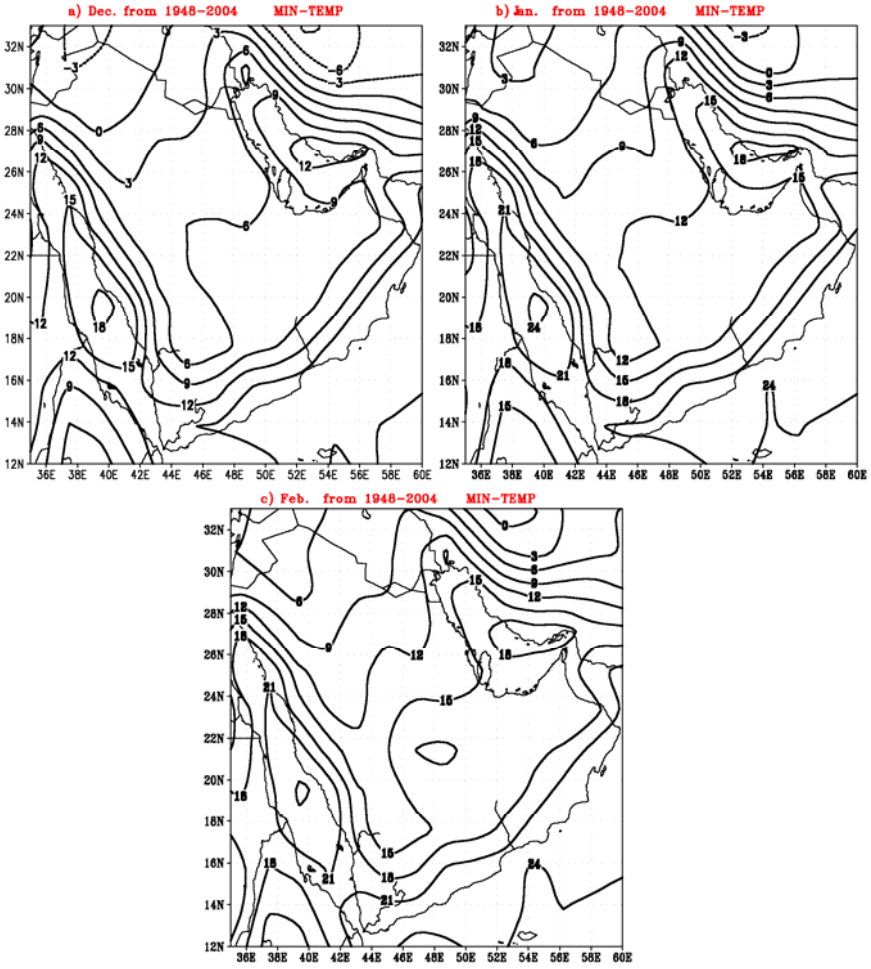

FIG. 2, The mean minimum temperature in winter months for the period from 1948 to 2004.

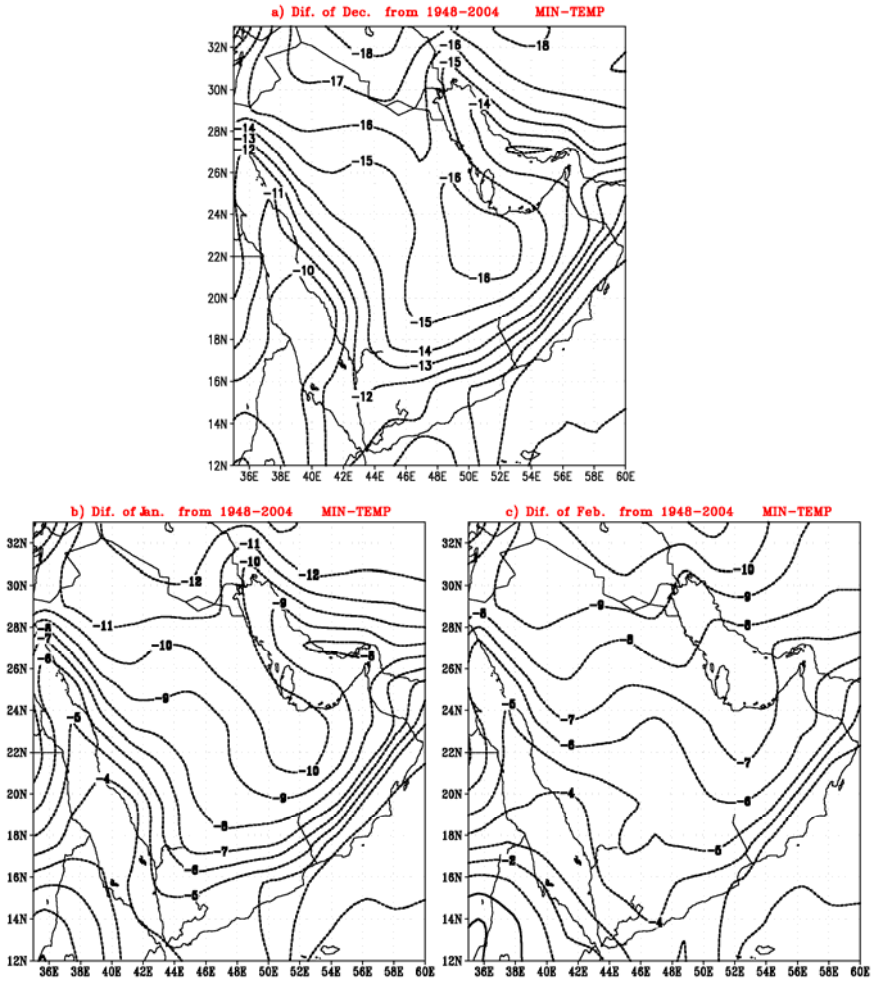

FIG. 3, The difference of mean minimum temperature in winter months from the average of the annual minimum temperature for the period from 1948 to 2004.

In general the difference in winter months becomes less wavy on February than the other two months. Also, the thermal ridge has difference values greater than those of the thermal trough, and the highest difference on thermal ridge is shifted from land area to water area in Arabian Gulf from December to February.

Spring Mean Temperature

Fig. 4, shows the minimum temperature of spring months, where one can observe the same thermal trough paralleled Red Sea as in winter months, and thermal low located to south western part of the KSA. Also, we recognize the thermal ridge oriented from southeast to northwest direction, and thermal high over the Al-Rub Al-Khali.

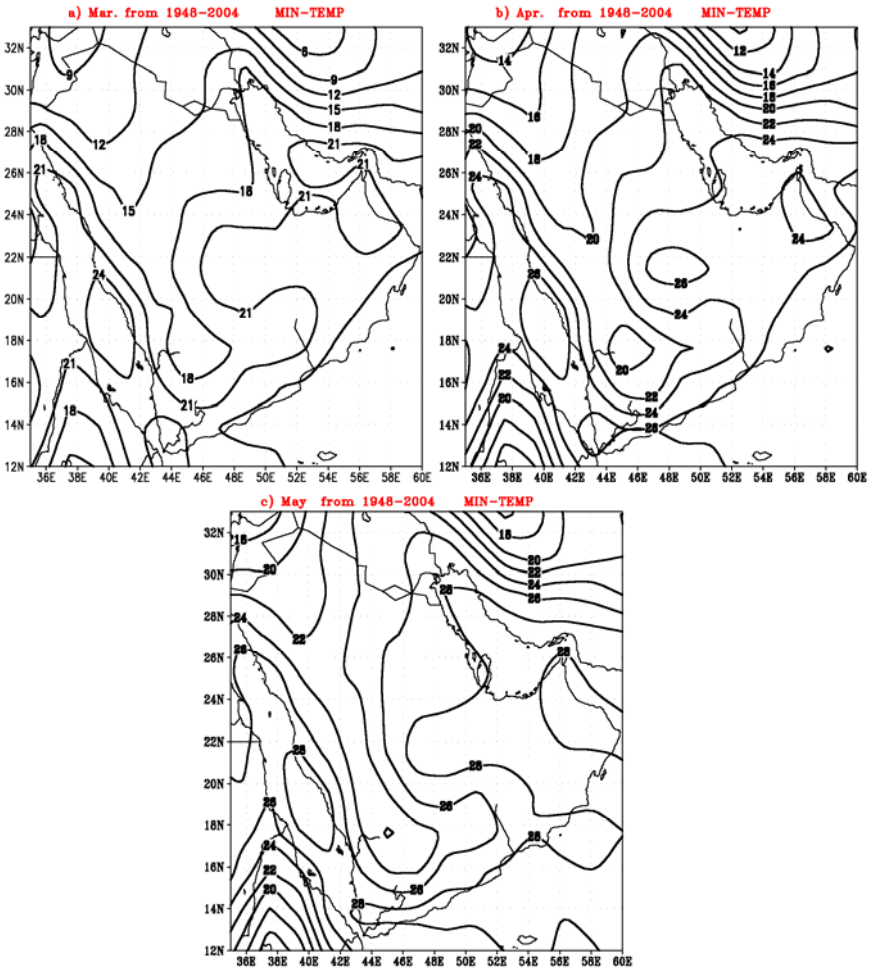

Figure 4: The mean minimum temperature in spring months for the period from 1948 to 2004.

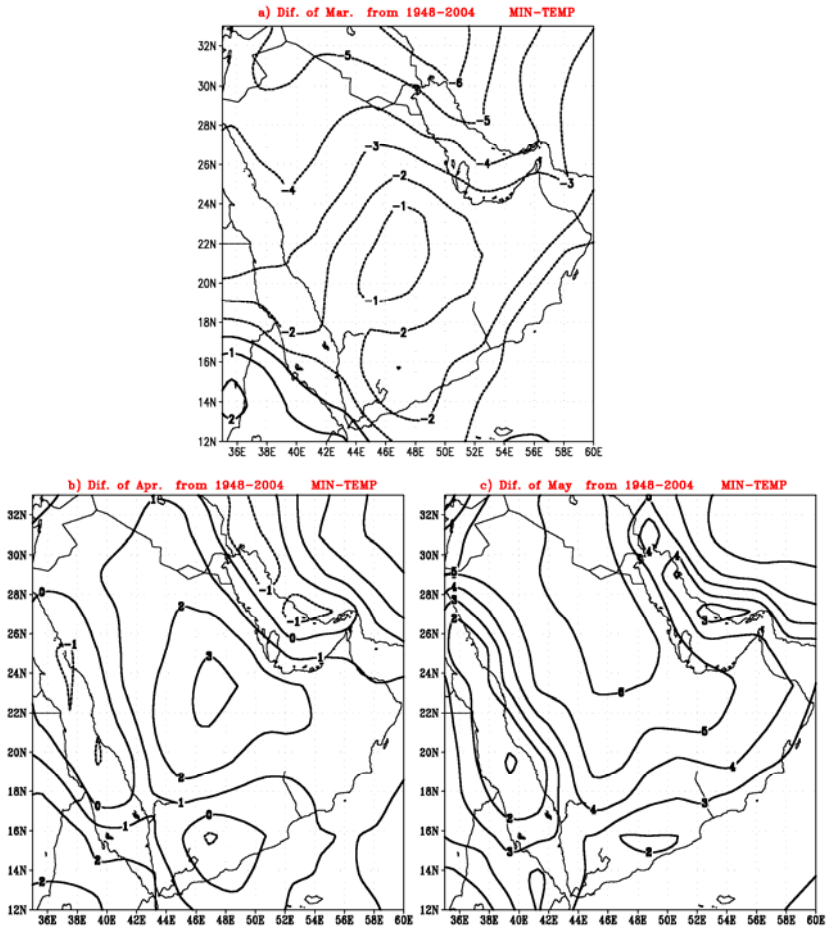

FIG. 5, The difference of mean minimum temperature in spring months from the average of the annual minimum temperature for the period from 1948 to 2004.

The strong gradient of the minimum temperature existed near Red Sea, while the gradient in the Arabian Gulf area was weak. The interesting point over the Arabian Gulf area is the formation of a permanent thermal high system on the area surrounding the United Arab Emirates.

Fig. 5, illustrates the difference of minimum temperature between the springs months mean and annual mean. The highest difference is located over the mid-interior land, while the lowest difference over water and surrounding areas, as expected. The interesting feature was found over Al-Rub Al-Khali area, where the difference is not much greater than the water area, and the gradient of the difference lines is weak compared the other areas of the KSA.

From the previous discussion, we can classify the KSA land into three areas, the first is the south-east area (or Al-Rub Al-Khali area) which represents the area effected strongly by water area or can be considered as an area of constant water vapor content. The second is the mid-area of KSA, that was affected much by land characteristics, while the third is the north-area, which has special characteristics affected by latitudinal distribution of heat or by Mediterranean systems.

Summer Mean Temperature

Fig. 6, shows the minimum temperatures of the summer months. It illustrates unexpected important distribution over the KSA, where the highest values existed on the eastern part of the Gulf area containing Al-Rub Al-Khali. The minimum temperatures over the Indian Ocean were in general less than the surrounding land.

Another important point is the lowest minimum temperature found on the east of both Red sea and Arabian Gulf. While the lowest minimum temperature east of the Red sea made thermal trough inside KSA and parallel the Sea, we found the highest minimum temperature form thermal high over Al-Rub Al-Khali.

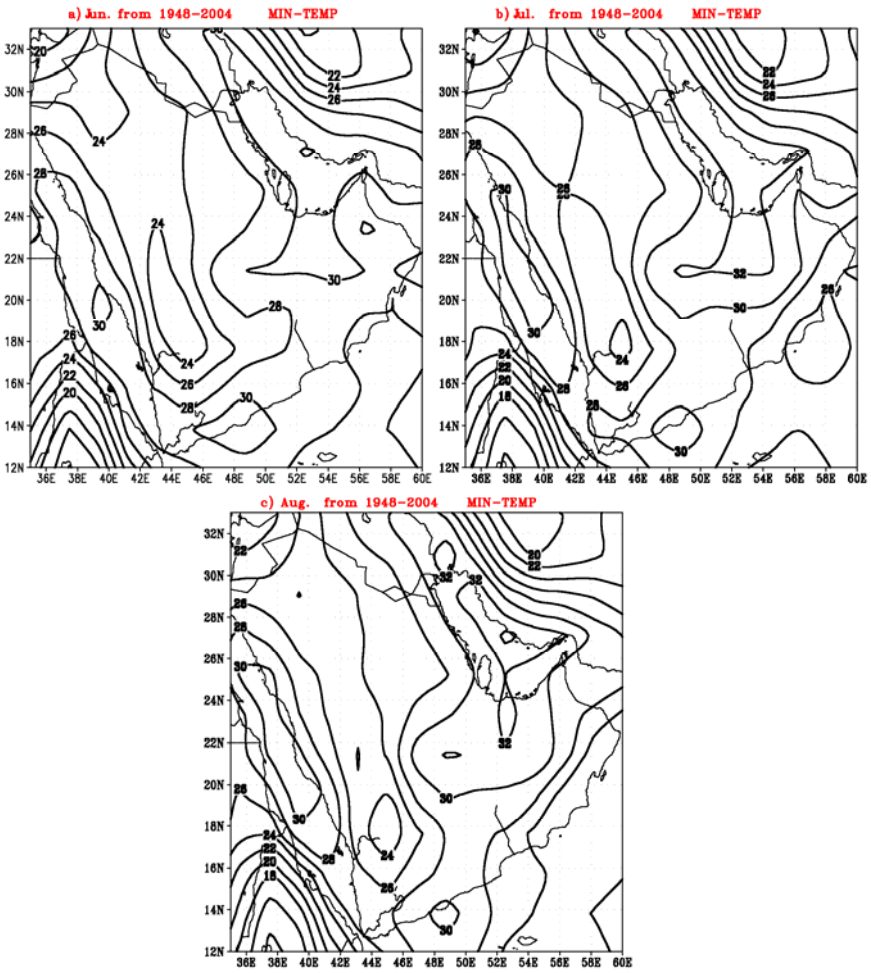

FIG. 6, The mean minimum temperature in summer months for the period from 1948 to 2004.

Fig. 7, shows the difference of the annual mean from the mean of minimum temperature of summer months. It shows that summer months had higher minimum temperatures than the annual mean and this difference was more pronounced and noticed in the northern part of the KSA. This may be related to the fact that the northern part has

high seasonal difference, or that it may be affected much by the Mediterranean sea systems. Also, it is noticed that the south-eastern part of the KSA, over the Al-Rub Al-Khali, had a second highest difference, because this area is always had a higher minimum temperature during all months of the year.

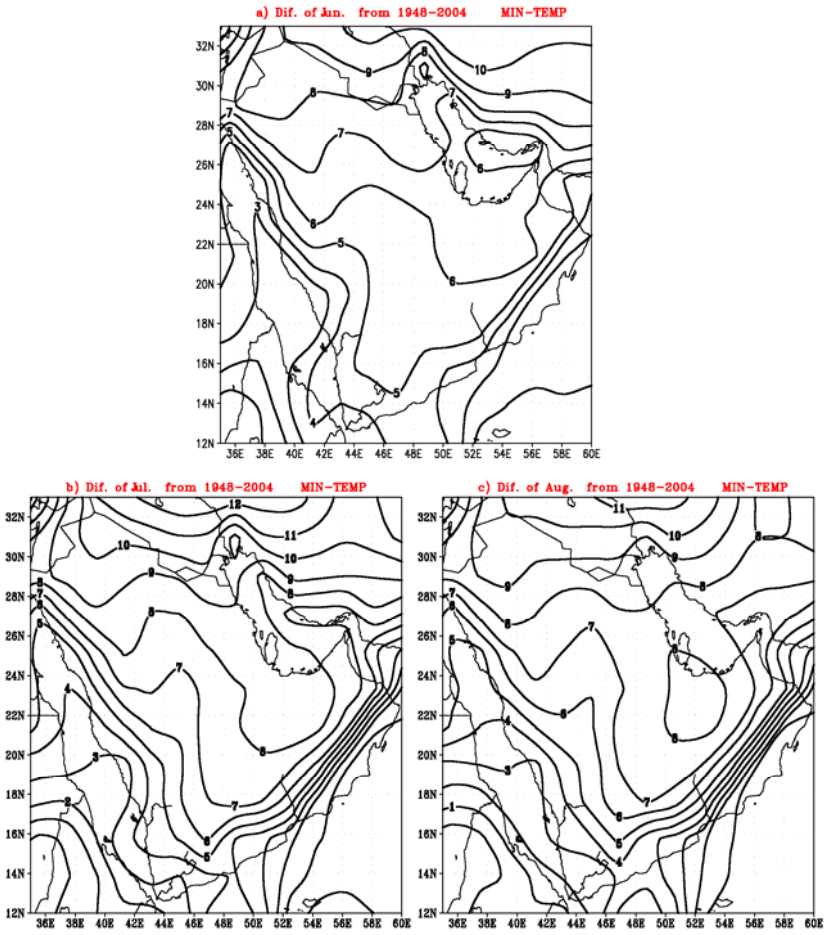

FIG. 7, The difference of mean minimum temperature in summer months from the average of the annual minimum temperature for the period from 1948 to 2004.

The important point here is that, the gradient of difference on land near the Indian Ocean is greater than that on land near Red Sea and Arabian Gulf, and one can conclude that the minimum temperature on Red Sea and Arabian Gulf is more stable than that on Indian Ocean.

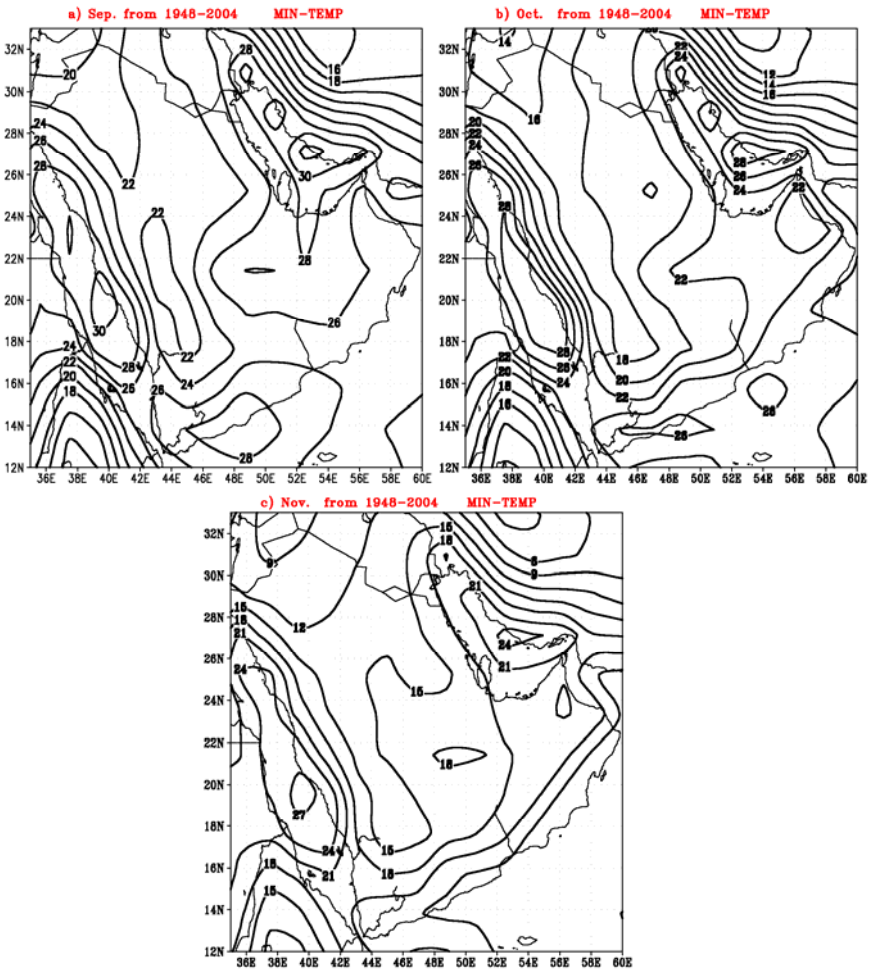

FIG. 8, The mean minimum temperature in autumn months for the period from 1948 to 2004.

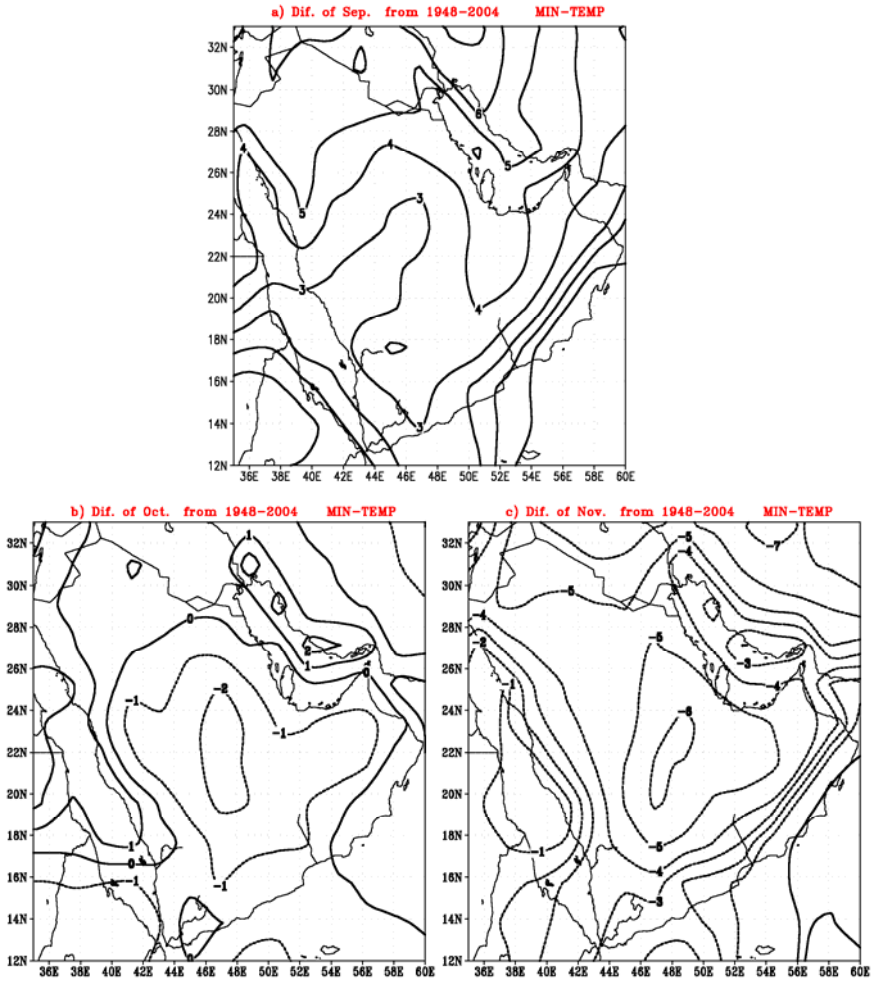

Figure 9; the difference of mean minimum temperature in autumn months From the whole year mean over the period from 1948 to 2004.

Autumn Mean Temperature

The general feature of the distribution of the minimum temperature over the KSA and surrounding area during the autumn is shown in Fig. 8. The figure shows that the highest minimum temperature was found over water area. The Indian Ocean showed

minimum temperature less than the Red Sea and the Arabian Gulf. The thermal low near the Red sea and the thermal high on the south eastern part of the KSA were still located on their places.

It is clear that the lowest minimum temperature over the Arabian Gulf during the month of September was higher than that on Red sea, whereas, November showed that the lowest minimum temperature is higher over Red sea than Arabian Gulf.

The difference in minimum temperature of autumn months is illustrated in Fig. 9. It shows a transfer from positive difference during the month of September to negative difference during November and the absolute lower difference in autumn was found on Red sea than Arabian Gulf and inside land.

Conclusion

From the previous discussion of the distribution of minimum temperature and their difference from annual mean on KSA and surrounding areas for the different seasons, we can conclude:

1), The area of interest can be classified into four regions with special characteristics:

a - The neighbor water region surrounding KSA from all direction except North.

b -The north region: the boundary of this region is from 25^{o}N to 32.5^{o}N and from 37.5^{o}E to 50^{o}N

c -The southwest region: its boundary is from 15^{o}N to 20^{o}N and from 42.5^{o}E to 47.5^{o}E.

d -The southeast region: with boundary from 17.5^{o}N to 25^{0}N and from 47.5^{o}E to 57.5^{o}E.

2), The area surrounding Al-Rub Al-Khali has small change in minimum temperature over the year, which means that this area has special characteristics in water content or may have special effective dynamic forces, while the north KSA has much seasonal difference affected by the Mediterranean sea systems.

3), The Red Sea minimum temperature is more stable, with less change than other areas on KSA, while the Indian Ocean and neighbor area minimum temperature is less stable.

4), Permanent thermal low in areas near Red Sea, and thermal high in areas surrounding Al-Rub Al-Khali are found.

The wave analysis of the special regions to specify the effective waves in their change, will be studied in the future

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التوزيع الفصلي لدرجات الحرارة الصغرى على المملكة العربية السعودية

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جدة – المملكة العربية السعودية

المستخلص . لدراسة التغير المكاني والزمانى لدرجة الحرارة الصغرى على المملكة العربية السعودية ، تم استخدام بيانات 57 سنة من البيانات المحللة فى مركز الانسب بامريكا والتي تمثل قياسات لدرجة الحرارة الصغرى لكل 6 ساعات. و لذلك تم عمل متوسطات مناخية سنوية وشهرية وحساب مدى الفروق الشهرية من المتوسط السنوي ودراسة التوزيع لهذه المتوسطات. و قد أظهرت الدراسة وجود منخفض حراري لدرجة الحرارة الصغرى دائم على البحر الأحمر ومرتفع حراري دائم على الربع الخالي.