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"REFRACTIVITY STATISTICS FOR TWO COUNTRIES IN THE MIDDLE EAST"

By

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ABSTRACT

This paper presents and compares the results of refractive index studies for Mersa Matrouh, Egypt, and Doha, Qatar. Statistics for surface refractivity and refractivity gradients at different heights from the surface are computed. The analysis indicate that these two locations suffer from nonstandard propagation conditions which persist even through the day time, particularly during the summer months.

1. INTRODUCTION

The propagation of electromagnetic waves in the lower troposphere is affected by any variation in its refractive index, n. In general, vertical variations in n are more important than horizontal variations. They cause the wave to follow a curved path with radius of curvature inversely proportional to the refractive index gradient.

For frequencies below about 30 MHz, straight line propagation can still be assumed by simply modifying the earth radius by an effective earth radius factor. On the other hand, at higher frequencies where the wavelength becomes comparable to the spatial fluctuations in refractive index, more pronounced effects are noticed. Several anomalous modes of propagation result causing the signal level to deviate either way from what would be expected under normal propagation conditions. The weakening in signal level is usually accounted for by the proper choice of a fade margin to be added to the transmitted signal.

However, as expected, any further signal reduction will cause a degradation in system performance. It should be pointed out that in wideband line of sight microwave systems, frequency selective fadings may occur. They cannot be rectified by simply boosting the transmitted signal level, and other techniques have to be employed. Inversely, although signal strengthening may seem to be a blessing, it can cause intersystem interference which is a major problem for national and international regulatory agencies.

2. INDEX OF REFRACTION

For radio frequencies below 30 GHz, the atmospheric index of refraction is given by

$$N = (n-1) \times 10^6 = 77.6\ P/T + 3.73 \times 10^5\ e/T_2 \qquad N - \text{Units} \qquad (1)$$

where P is the total pressure in mB, T the temperature in °K and e the partial water vapor pressure in mB. Since n is close to unity with variations in the fourth decimal digit, it is more convenient to define and work with the refractivity N as given by equation (1). In fact, this equation is in general usable up to 1000 GHz outside the absorption bands [1]. Equation (1) can be subdivided into two terms: the dry term 77.6 P/T and the wet term $3.73 \times 10^5\ e/T_2$. It would seem that an increase in temperature would reduce the wet term faster than the dry term, but the consequent increase in the capability of the atmosphere to carry more water vapor may overcompensate the temperature effect resulting in a pronounced increase in the wet term and consequently N. This is mainly the reason for the higher values of N observed during the summer compared with the winter. The relative importance of the water vapor content can be depicted by evaluating the differentials of equation (1).

$$\Delta N = 0.27\ \Delta P - 1.40\ \Delta T + 4.50\ \Delta e \qquad N - \text{Units} \qquad (2)$$

for typical conditions of P = 1000 mB, T = 288 °K and e = 12 mB. The large contribution of e is caused by the fact that water vapor molecules have a permanent electric dipole moment which can be easily polarized in the presence of radio waves, resulting in a high dielectric constant for water vapor.

Under normal conditions, the pressure, temperature and relative humidity decrease with height causing a decrease in N with a gradient of −40 N−units/km in temperate climates. Steeper gradients in N may be caused by either temperature inversions and/or steeper gradients in relative humidity.

According to the CCIR study groups 10 and 11 recommendation 370−4, the median field strength at VHF and UHF in North America and Western Europe can be correlated with the refractivity gradient in the first km defined by

$$\Delta N(1000) = N_1 + N_s \quad N - \text{Units} \tag{3}$$

where N_s is the surface refractivity evaluated at 1 km above the surface. Since values of $\Delta N(1000)$ are not always available, correlation between N_s and $\Delta N(1000)$ have been investigated in several regions of the world [2,3,4], and an exponential relationship of the form.

$$\Delta N(1000) = -A\exp(BxN_s) \tag{4}$$

has been suggested, with A and B varying according to climates, see Table (1). Thus the field strength can now be directly correlated to the more widely available N_s with acceptable results especially for temperate climates. Refractivity gradients over other heights are also sometimes quoted. For example, $\Delta N(75)$ and $\Delta N(150)$ are particularly relevant to ground ducting of radio waves over transhorizon paths, while $\Delta N(500)$ is important for troposcatter links since the bottom of the volume common to the beams of both transmitter and receiver antennae is below 500 meters [5].

Table 1 – Coefficients for the exponential relation between N_s and $\Delta N(1000)$.

A	B	Region
7.320	0.005577	USA
9.300	0.004565	Germany
3.350	0.007200	UK
2.060	0.009370	Argentina
3.420	0.007580	Japan
2.300	0.008630	Africa
0.239	0.015971	This study
0.350	0.014833	This study
0.256	0.015889	This study

3. DATA DESCRIPTION

The results presented in this paper are based on radiosonde data collected in Mersa Matrouh, Egypt, and Doha, Qatar, by the corresponding meteorlogical departments in these two countries. Although the use of this type of data, which is not originally intended for N calculations, suffers from several drawbacks [6], in most cases it is the only available one and still constitutes a valuable source for long term statistical investigations. The two cities lie on the boundary between the sea and the desert and are therefore considered good examples of hot and humid coastal areas where anomalous propagation modes are likely to occur.

Only few attempts have been made to study refractive index variations in Egypt [6,7,8]. On the other hand a more extensive study sponsored by Gulfvision under the supervision of the International Telecommunication Union was conducted in the early eighties to investigate the refractivity effects on VHF and UHF signals in the Gulf area. The program consisted of analysis of radiosondes available from several weather stations, refractivity measurements along installed masts and signal level measurements at different points in the area. The main conclusion of this study was that the area is a notable super refractivity area with the presence of ducts for a large percentage of time persisting even through day-time, with normal refraction occurring only for small percentage of time. Although the study also showed a correlation between surface refractivities at different locations in the Gulf, including Qatar, no upper air refractivity measurements were conducted in this country to investigate the presence of similar correlations.

The weather station in Mersa Matrouh is located 28 meters above sea level. The data base comprises instrumented balloon sondings twice daily for a two-year period from August 1980 until August 1982. Data for August 1981 were missing. As for the Doha station. 10 meters above mean sea level, the data only comprises twice daily balloon sonding results during the upper air measurement program from June 1985 until December 1985. Throughout the analysis day and night data have been separated in order to emphasize the presence of abnormal propagation modes even during day-time.

4. NUMERICAL RESULTS FOR MERSA MATROUH

The refractivity profiles up to about 1 km for a number of days in August 1980 are plotted for the day-time and night-time readings in Figure 1 (a) and (b) respectively. As expected marked variations from standard conditions are present in the night profiles with the formation of ducts, elevated layers and subrefraction conditions. The presence of these nonstandard situations can also be noticed in the day profiles. Analysis of the day data indicates that these are mainly due to the presence of large humidity gradients rather than temperature inversions. For comparison, Figure 1 (c) and (d) shows the profiles for January 1981. In general, they follow nearly the standard gradient with the night profiles having more variations. The surface refractivity results are summarized in Figure 2. In general, the mean values of N, are higher in summer months compared to the winter months. The actual values ranged from a maximum of 389 N-units for a day reading in August to 284 N-units for a night reading in July. The standard deviation from the averages in the winter months is lower than in the rest of the year, with the night values being higher than the day values. The mean value of the dry term component is lower for the summer months and day readings with relatively small standard deviations not exceeding 4.63 N-units. As for the wet term, it follows exactly the opposite pattern with standard deviations varying between 9.2 and 18.5 N-units. The opposing behavior between night and day of both dry and wet terms resulted in practically identical N, monthly mean patterns for the two periods.

Figure 3 shows the monthly mean values of $\triangle$ N (1000) with the corresponding maxima, minima and standard deviations. The values of mean $\triangle$ N(1000) were equal to or steeper than the standard value of $-$ 40 N $-$ units/km except for the day readings of the winter months. The standard deviations ranged from 7.63 to 26.16 N-units/km. The steepest gradient observed was $-$ 121 N $-$ units/km while subrefraction conditions occurred only in August 1980 for both day and night readings. The A and B coefficients of the exponential relationship relating N, and $\triangle$ N (1000), computed from the actual day data, the actual night data and the whole period monthly averages respectively are given in table 1. Compared to other regions of the world, including values published for Africa [3], the values for A are one order of magnitude smaller while the values of B are higher.

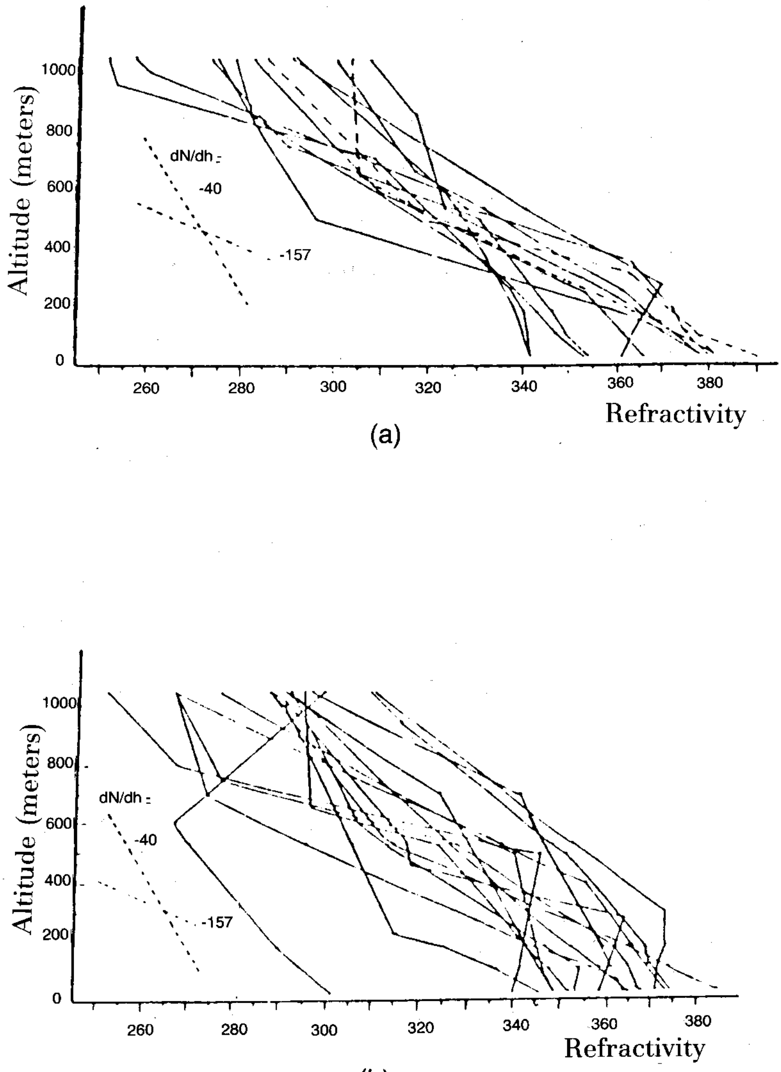
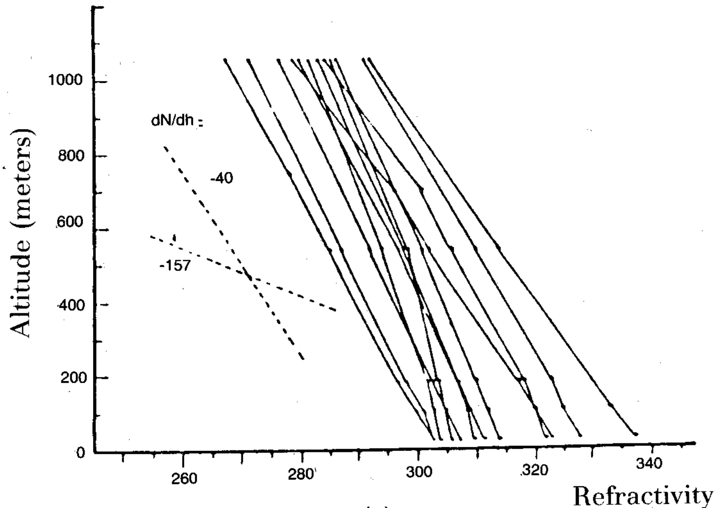
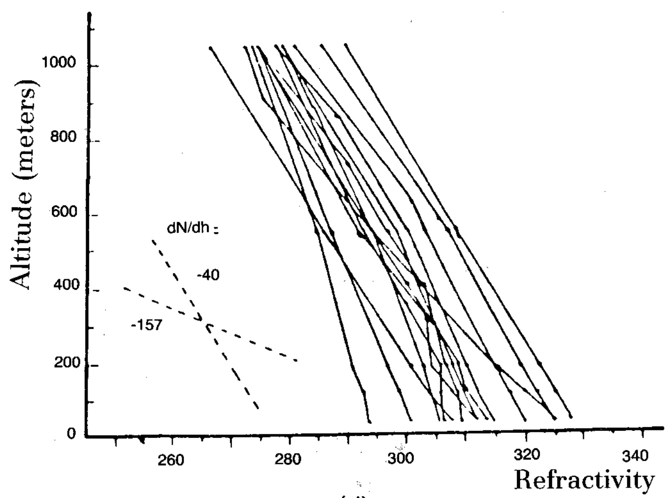


Fig. 1 : Refractivity profiles for Mersa Matrouh, (a) day-time profiles in August 1980, (b) night-time profiles in August 1980, (c) day-time profiles in January 1981, (d) night-time profiles in January 1981.



(c)



(d)

Fig. 1 : Refractivity profiles for Mersa Matrouh, (a) day-time profiles in August 1980, (b) night-time profiles in August 1980, (c) day-time profiles in January 1981, (d) night-time profiles in January 1981.

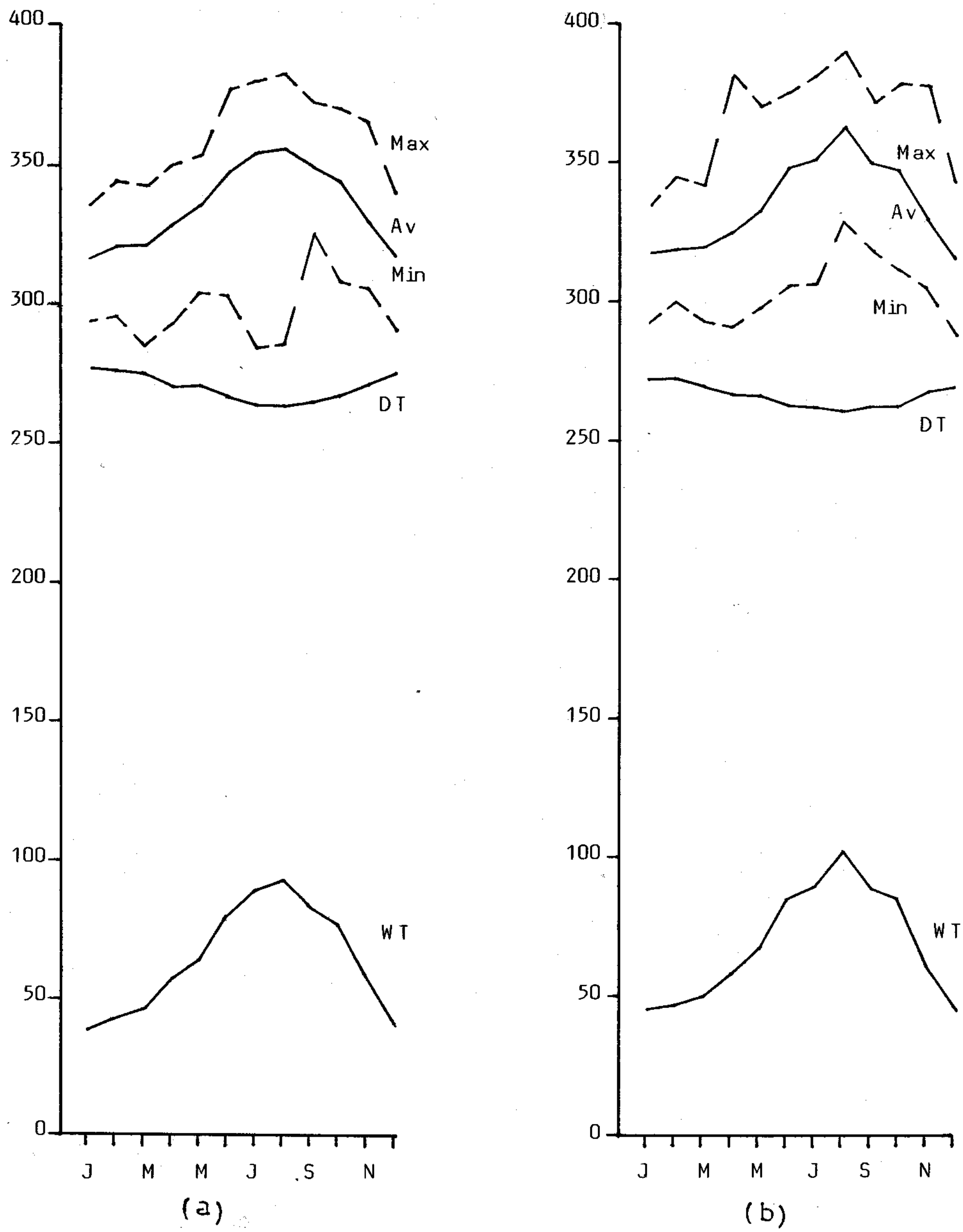


Fig. 2 : Monthly behavior of the mean dry term, wet term and surface refractivity with the corresponding maxima and minima for Mersa Matrouh, a) night-time readings, b) day-time readings.

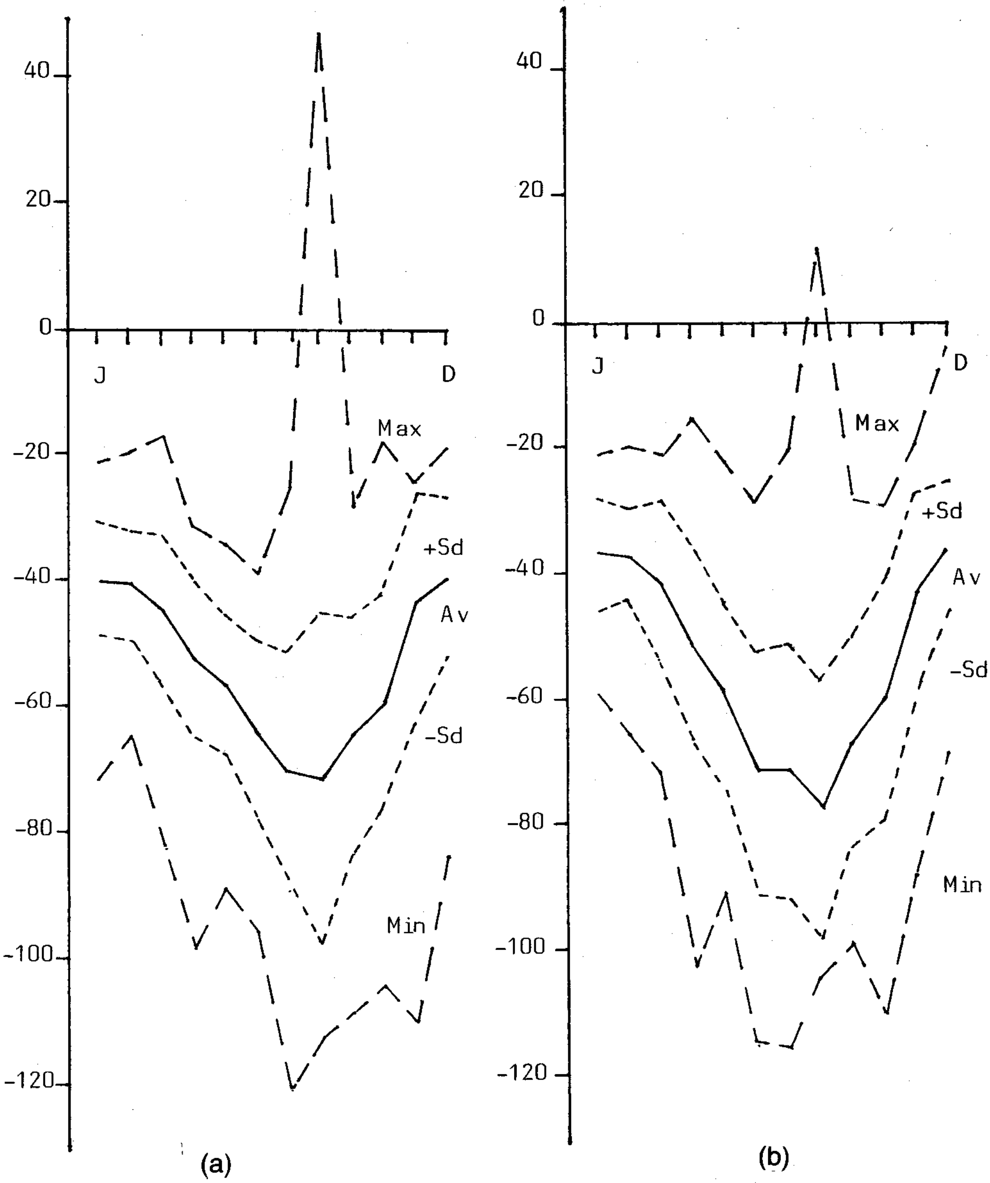


Fig. 3 : Monthly behavior of mean △ N (1000) with monthly maximum, minimum and one standard deviation indicated in Mersa Matrouh, (a) night-time readings, (b) day-time readings.

Figures 4 and 5 show results for △ N (75) and △ N (150) respectively. Although the mean gradients do not exceed − 85 N − units/km, the large values of standard deviations indicate more activities near the earth' s surface for both day and night readings.

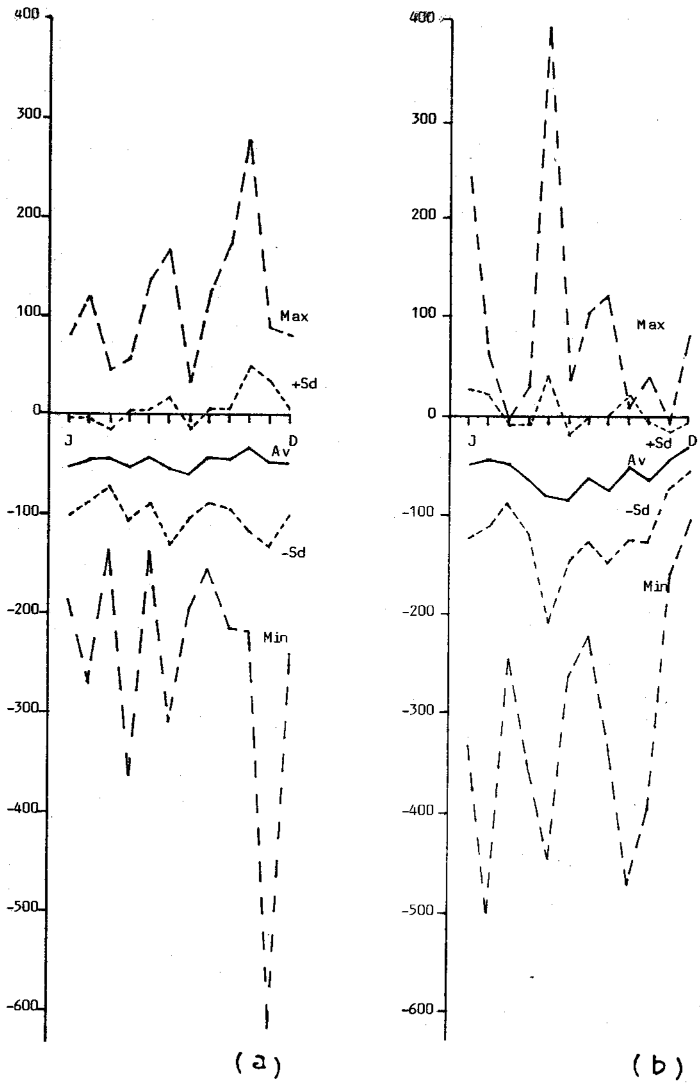


Fig. 4 : Monthly behavior of mean △ N (75) with monthly maximum, minimum and one standard deviation indicated in Mersa Matrouh, (a) night-time readings, (b) day-time readings.

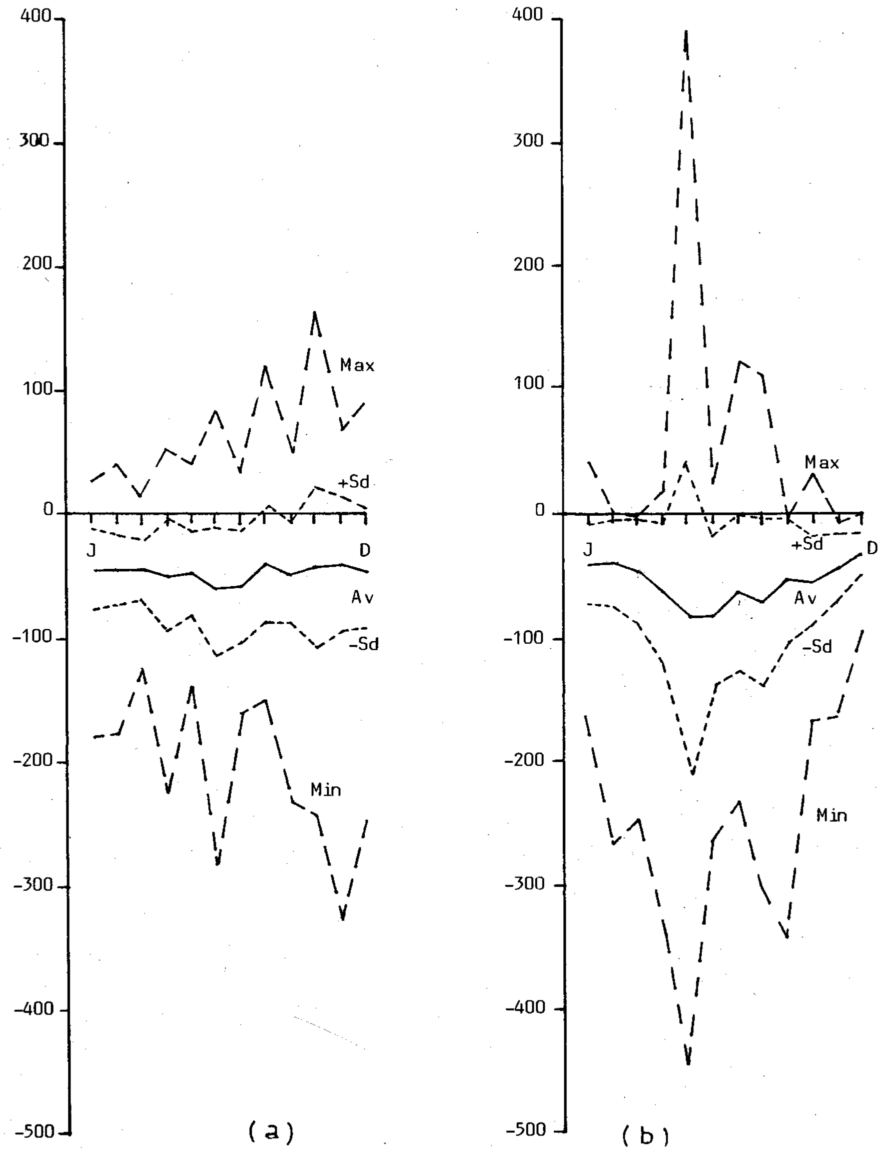


Fig. 5 : Monthly behavior of mean △ N (150) with monthly maximum, minimum and one sandard deviation indicated in Mersa Matrouh, (a) night-time readings, (b) day-time readings.

5. NUMERICAL RESULTS FOR DOHA

Figure 6 shows the mean surface refractivity for the limited period of observation of 7 months. In contrast with the Mersa Matrouh results there are marked differences between night and day, with larger mean values in summer months. Furthermore, larger standard deviations were observed, reaching 37.36 N-units in July, and being higher for the day readings. The highest N_s computed was 415 N-units for a night in July while the lowest N_s was 264 for a day also in

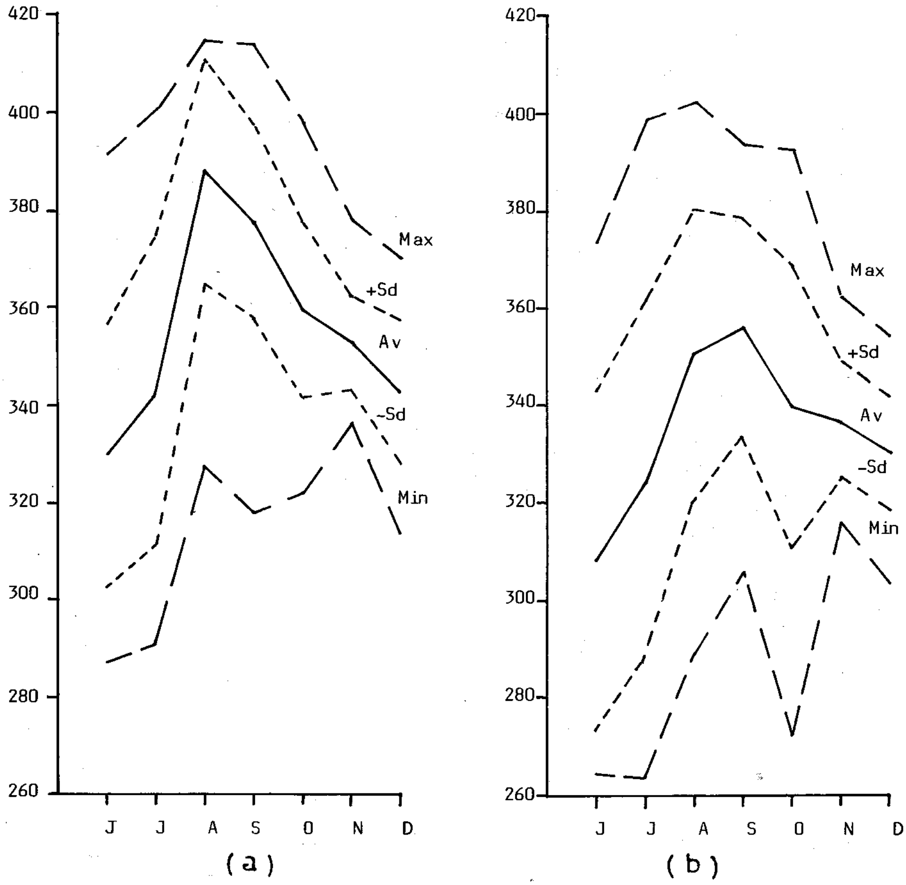


Fig. 6 : Monthly behavior of mean N_s for Doha, with monthly maximum, minimum and one standard deviations indicated, (a) night-time readings, (b) day-time readings.

July. Results for △ N (1000) are presented in Figure 7. The average gradients are steeper during the summer months and for night readings ranging from −45.21 N− units/km for the day readings in December to −140.48 N−units/km for the night readings in August. Once more, the standard deviations are high, reaching 33 N-units/km in June. On one end, the steepest observed △ N (1000) was −185 N−units/km, and on the other end, it was −14 N− units/km. The values previously published for Bahrain [4] lie somewhere between the day and night monthly mean values obtained in this study, As for the A and B coefficients, the computations yielded values of 1.136 and 0.0122 respectively. Earlier results for Bahrain gave 0.3 and 0.016 for the summer and 0.33 and 0.0157 for the winter respectively [4].

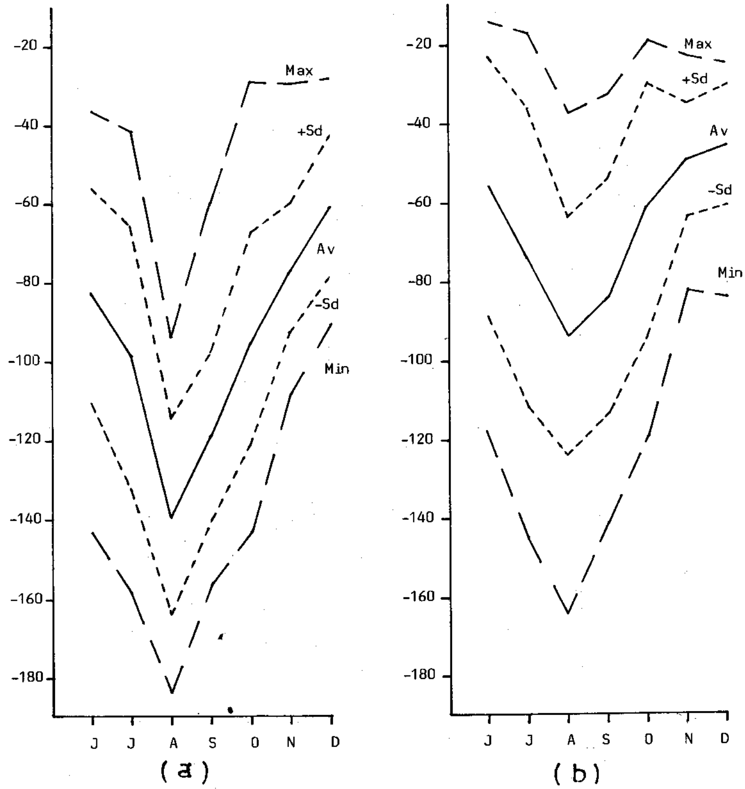


Fig. 7 : Monthly behavior of mean △ N (1000) for Doha, with maximum, minimum and one standard deviation indicated, (a) night-time readings, (b) day-time readings.

Figures 8, 9 and 10 represent △ N (30), △ N (74) and △ N (150) respectively. Both subrefraction and superrefraction conditions were noticed in both day and night readings with the steepest negative gradients occurring during the nights. In these results also, the activites increase as we approach the earth's surface as indicated by the large values of standard deviations.

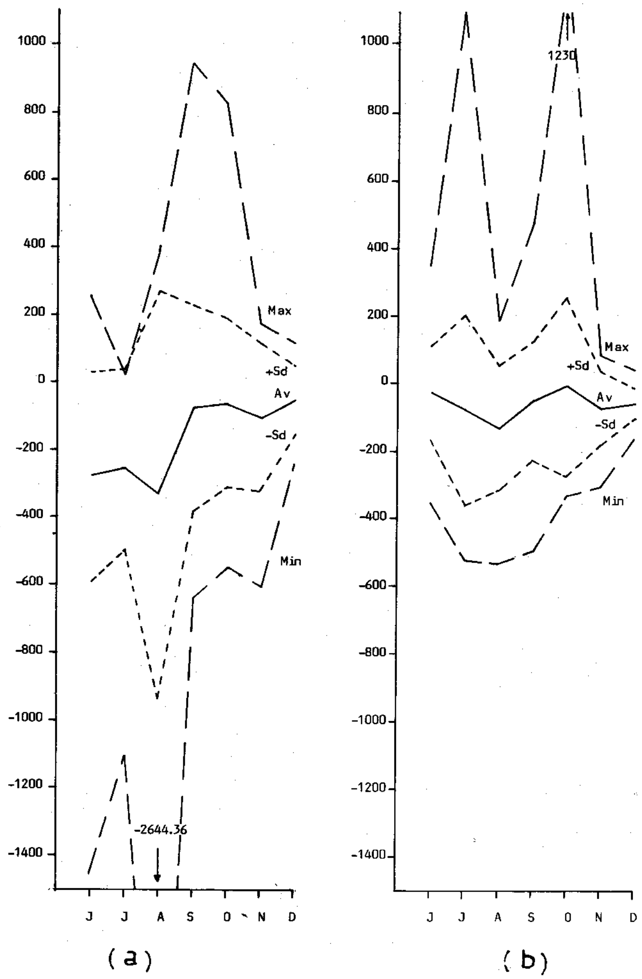


Fig. 8 : Monthly behavior of mean △ N (30) for Doha, with maximum, minimum and one standard deviation indicated, (a) night-time readings, (b) day-time readings.

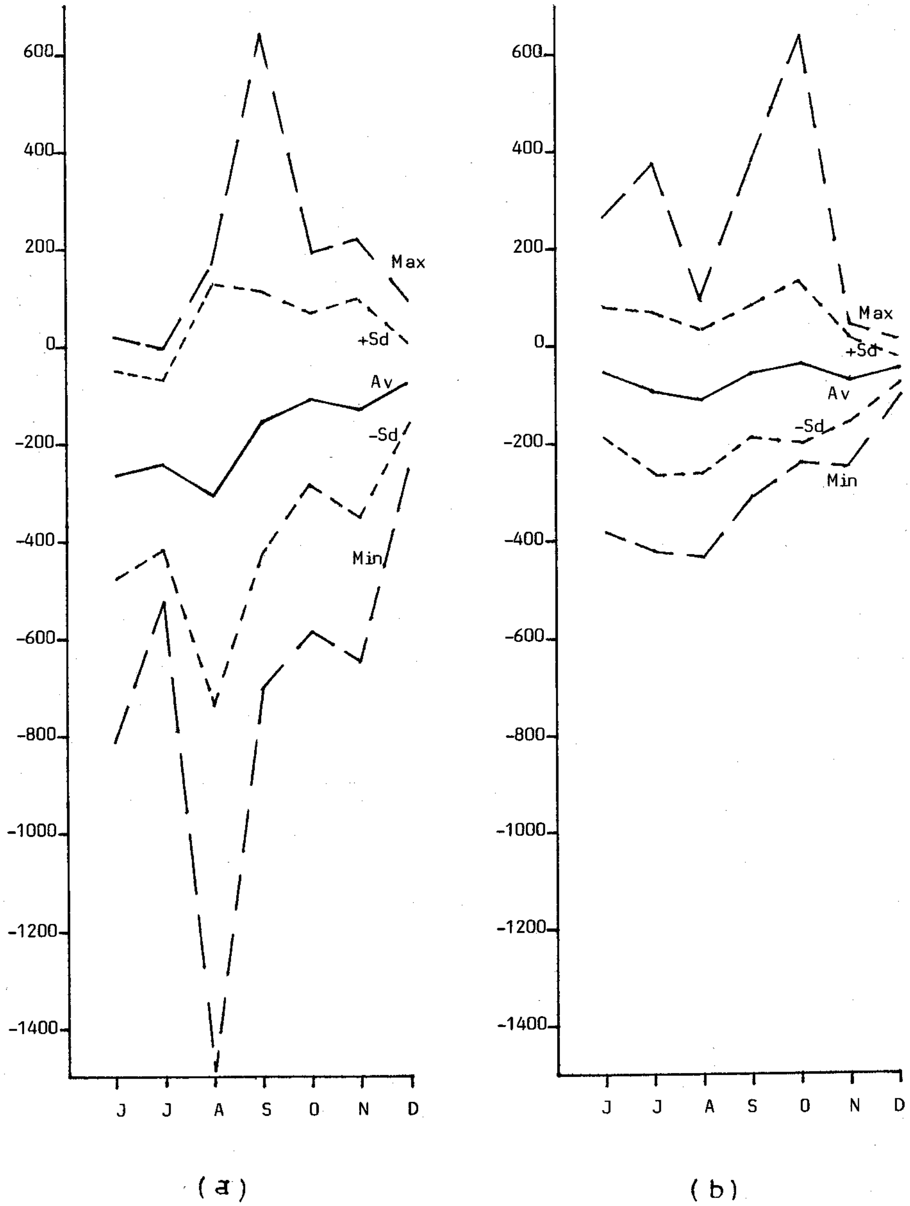


Fig. 9 : Monthly behavior of mean $\triangle$ N (74) for Doha, with maximum, minimum and one standard deviation indicated, (a) night-time readings, (b) day-time readings.

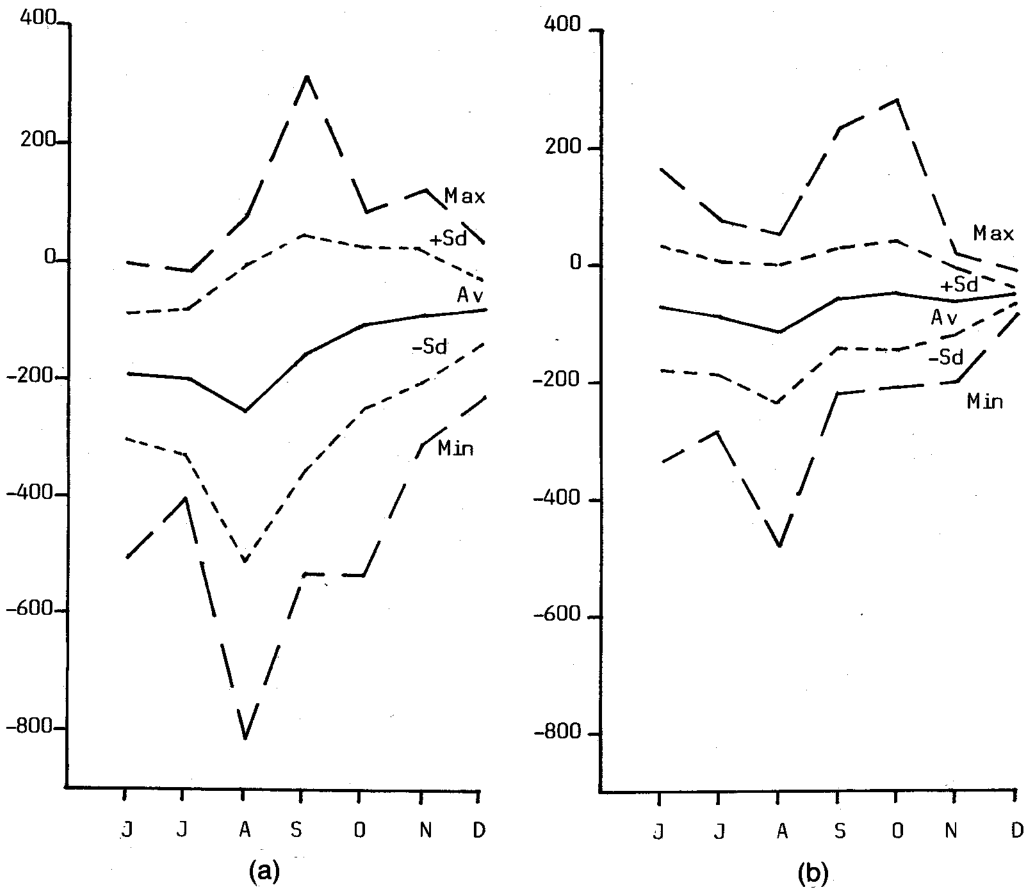


Fig. 10 : Monthly behavior of mean Δ N (150) for Doha, with maximum, minimum and one standard deviation indicated, (a) night-time readings, (b) day-time readings.

6. CONCLUSIONS

The two examples presented in this study suffer from large variations in refractive index gradients with the Gulf area results, as expected, being more pronounced. The activities persist through the day-time, particularly during the summer months. The differences between night and day results are more profound in Doha than in Mersa Matrouh, where the distribution of N_s is almost identical during the two periods.

The importance of further studies of this phenomenon in this area is emphasized by the growing demand and utilization of microwave systems for civil and military purposes. The design and installation of radio relay links, radar and air traffic control systems, FM and TV broadcasting services are but a few of many applications requiring the proper knowledge of statistics for this phenomenon. The use of appropriate measuring techniques is an important goal that has the be pursued.

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