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REFRACTIVITY DISTRIBUTIONS FOR 48 LOCATIONS IN EGYPT

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Abstract

Meteorological data are used to calculate the average monthly values of surface refractivity in 48 locations in Egypt. Comparisons with the few previously reported data are presented. An investigation of the variation of the monthly average refractivity and the spread between maximum and minimum monthly values among the different locations is performed. Finally upper air results are given for three locations.

1. Introduction

The atmospheric refractivity at the surface N_s and its first-kilometer gradient ΔN are parameters commonly used by radio engineers in the design of the different radiowave communication systems. Contours of mean monthly values of N_s and ΔN have been generated on a global basis using 5-year data from 112 radiosonde stations [1]. However, the information regarding some parts of the world is still scarce in addition to the fact that longer periods of data would yield more accurate estimates of the long term averages. Therefore, the CCIR has encouraged the national administrations to come up with more detailed analysis for their territories. In this work, monthly mean values of N_s at 48 locations that cover most climatic and topographic regions in Egypt are presented along with monthly mean values of ΔN at three locations.

2. The Data Base

The analysis is based on data published in the Climatological Normals for Egypt [2]. Unfortunately, it was in the form of monthly average values of pressure p, temperature T and relative humidity RH. In order to validate the use of this data, a comparison was made between the N_s values published in the world Atlas for atmospheric radio refractivity [1] and those obtained in this study. It should be mentioned that the formers were calculated by substituting the readings of p, T, and the water vapour pressure e in

$$N = 77.6 \frac{p}{T} + 3.7 \times 10^5 \frac{e}{T^2} \qquad \Delta\text{ N-units} \qquad (1)$$

and then averaging the values for each month for 5 years. Table 1 shows the comparison for the only three locations in Egypt available in the World Atlas. The maximum difference does not exceed 2.3, 1.7 and 0.9 % for Aswan, Mersa Matruh and Cairo respectively.

The results of a more detailed comparison carried on with a previous study for Mersa Matruh [3,4] is shown in Tables 1 and 2. The relative error in N_s never exceeded 2.5%. The corresponding errors in the dry term (77.6p/T) and the wet term ($3.7x10^5$ e/T^2) of the refractivity were less than 1 and 13% respectively. The high relative error in the wet term is understandable bacause of the usually large variability in the humidity content. Due to the peculiar location of Mersa Matruh which is influenced from the south by the desert and from the north by the mediterranean sea, it is believed that these errors will hardly be exceeded in the other locations.

From the above two comparisons, one can conclude that the type of data used in this study give results within an acceptable range of errors and therefore it can be employed in cases where original data is not available. Figure 1 shows the locations of the 48 weather stations. These locations are classified into 9 regions according to their climatic and topographic natures. These regions are: 1-Mediterranean coast (stations 1-12), 2-Red sea (13-18), 3- Delta (19-24), 4- East Delta (25-27), 5- West Delta (28-31), 6-Mid Sinai (32-34), 7- Mid Egypt (35-41), 8- Upper Egypt (42-44) and 9- Western desert (45-48). The data for each location is based on daily measurements ranging from 3 to 8 readings with a collection period exceeding 10 years for 37 locations.

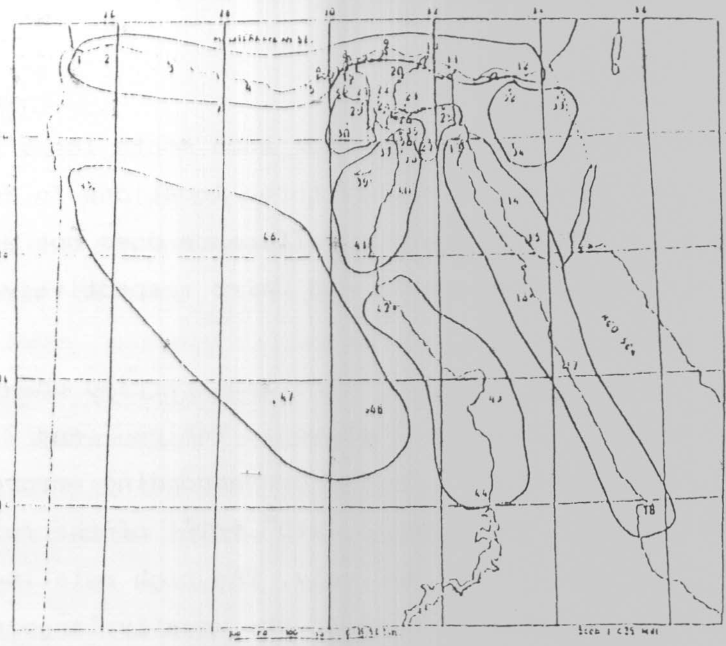


Figure 1. Map of Egypt showing the locations of the weather stations.

	ASWAN		CAIRO		MERSA MATRUH		
	A	B	A	B	A	B	C
JAN	299	295	314	315	319	320	317
FEB	287	288	312	314	319	320	320
MAR	280	281	313	313	321	321	320
APR	280	276	313	314	323	324	326
MAY	278	275	318	317	336	333	335
JUN	276	276	329	328	348	347	348
JUL	285	282	341	341	361	359	352
AUG	288	286	347	346	361	362	360
SEP	291	288	338	341	345	351	349
OCT	294	289	334	334	340	341	346
NOV	299	298	331	327	334	333	330
DEC	305	298	322	319	323	323	315

Table 1. Comparison between the monthly average N_s in the World Atlas (A) [1] and this study (B) for Aswan Cairo and Mersa Matruh. Also shown are the results published in a previous study for Mersa Matruh (C) [4].

	Dry Term		Wet Term	
	A	B	A	B
JAN	275	275	45	42
FEB	275	275	45	45
MAR	273	272	49	48
APR	270	269	54	58
MAY	267	269	66	66
JUN	264	265	83	83
JUL	262	263	97	90
AUG	262	262	100	98
SEP	264	264	88	86
OCT	267	265	75	81
NOV	270	270	63	60
DEC	274	273	49	43

Table 2. Comparison between the dry and wet terms of the monthly average N_s in Mersa Matruh in reference [4] (A) and this study (B).

3. Numerical Results

A comparison between the monthly average N_S in all locations indicates that the eastern part of the mediterranean coast has always the highest values with the maximum of 372 N-units occurring in August at El Arish (location 12). On the other hand, the lowest values always occurred in Aswan (44) with the minimum of 275 N-units in May. In northern Egypt, August and February are the months with the highest and lowest monthly average N_S respectively. As we move southwards, they shift towards November and May.

Table 3 shows the spread between the maximum and the minimum monthly mean values for the dry term, the wet term and N_S for the 48 locations. As expected the spread in the dry term is smaller than the corresponding value in the wet term. The former has its lowest values on the mediterranean coast averaging 14 N-units and its highest values

Loc.	ΔDT	ΔWT	ΔN_s	Loc.	ΔDT	ΔWT	ΔN_s
1	13.4	53.3	40.7	25	16.2	47.1	33.3
2	13.5	58.6	45.9	26	15.1	51.9	38.8
3	13.6	55.6	42.4	27	16.8	42.6	30.2
4	14.4	56.2	42.5	28	14.8	47.3	34.2
5	14.0	51.7	38.1	29	15.5	50.7	36.8
6	12.7	54.2	41.6	30	15.4	44.1	29.9
7	14.1	53.2	40.0	31	15.2	43.5	31.6
8	14.5	54.3	39.8	32	13.6	42.2	34.9
9	13.5	52.4	39.7	33	16.3	41.9	27.9
10	14.3	54.9	41.5	34	18.5	40.4	27.7
11	14.4	55.6	42.0	35	15.4	47.9	34.8
12	14.9	61.7	47.2	36	15.3	46.1	33.1
13	15.4	46.8	35.1	37	16.5	49.6	34.8
14	15.1	53.7	39.1	38	16.2	43.7	33.0
15	15.4	56.6	42.0	39	17.4	43.6	28.4
16	16.0	40.6	25.9	40	18.2	41.1	28.9
17	13.5	41.2	28.5	41	18.2	43.5	29.1
18	15.0	22.7	29.0	42	17.4	31.6	24.9
19	14.9	54.3	40.2	43	19.9	21.2	21.2
20	15.6	51.6	36.0	44	18.7	16.7	23.1
21	15.0	47.5	33.9	45	18.8	31.4	19.4
22	15.4	53.3	39.3	46	18.0	31.5	24.4
23	14.8	46.8	34.7	47	19.9	21.5	18.6
24	15.8	50.0	36.3	48	19.1	20.7	19.6

Table 3. The spread between maximum and minimum monthly mean values of the surface refractivity ΔN_s, its dry ΔDT and wet ΔWT terms for the 48 locations.

in the western desert averaging 19 N-units. On the contrary, the spread in wet term is highest on the mediterranean coast averaging about 55 N-units and decreases as we move southwards to its lowest value of 16.7 N-units in Aswan. Since in general an increase in T decreases the dry term while increases the wet term due to the overcompensating effect of the subsequent increase in humidity, the spread in N_s is more moderate than that in the wet term. Nevertheless, it follows the same pattern being maximum in the north while decreasing as we move southwards. It has its highest value of 47.2 N-units in El Arish (12) and its lowest of 18.6 N-units in Dakhla (47).

In order to be able to draw contour maps, the effect of the station height on the refractivity should be eliminated by reducing its value to that at mean sea level through the following relationship

$$N_o = N_s \exp(h/H) \qquad (2)$$

where h is the station height in km and H is a scale height parameter assumed 7 [5]. The monthly distributions of N_o are shown in Figure 2 for the 48 locations grouped into 9 regions. The similarity in the patterns in each region is clear with only few exceptions. For example, the first three locations in the Red sea region (13-15) which lie on the Gulf of Suez have similar patterns but different than the rest of the locations further to the south with Ras Benas (18) having a completely different one.

In inland Sinai, El Maghara (32) exhibits two peaks of N_o . This is probably due to both its high altitude (323.5 m) and its proximity to the northern coast. However, it should be mentioned that, for this location, data was available for only one year.

Table 4 presents the annual mean value of N_o for all the locations along with the number of months N_o exceeds 350 N-units. As in the case of N_s, the maximum value (344 N-units) occurs on the mediterranean coast at Port Said (11) and El Arish (12) while the minimum (244 N-units) occurs in Aswan (44).

Figure 3 gives the monthly average values of the first kilometer gradient of the refractivity in Mersa Matruh, Helwan and Aswan. These are the only locations where upper air data is collected in Egypt. Unfortunately, some of the monthly data where not reported in reference [2]. Since data are given only for fixed pressure levels, linear interpolation was used to estimate the corresponding values at

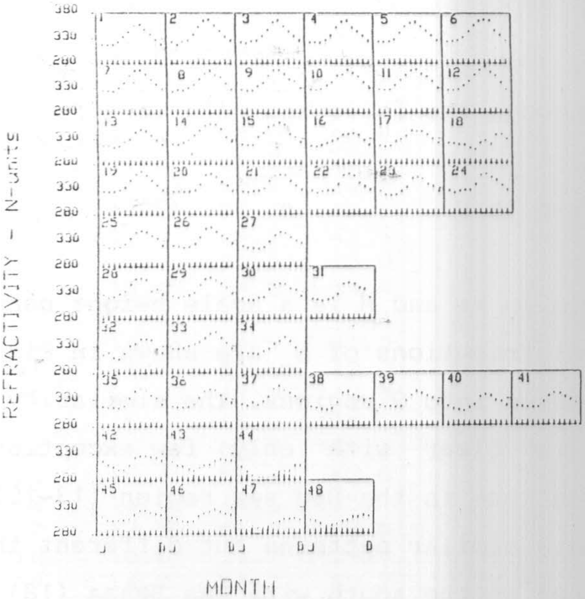
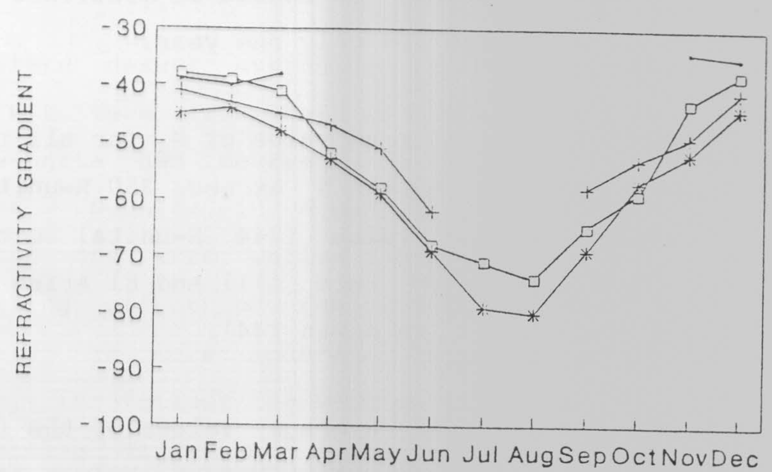


Figure 2. Average monthly distributions of the mean sea level refractivity for the 48 weather stations. 1- Mediterranean coast (1-12), 2- Red sea (13-18), 3- Delta (19-24), 4- East Delta (25-27), 5- West Delta (28-31), 6- Mid Sinai (32-34), 7- Mid Egypt (35-41), 8- Upper Egypt (42-44), 9- Western Desert (45-48).



		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ASWAN	·	-39	-40	-38								-34	-35
HELWAN	+	-41	-43	-45	-47	-51	-62			-58	-53	-49	-41
MERSA MATRUH	*	-45	-44	-48	-53	-59	-69	-79	-80	-69	-57	-52	-44
MERSA MATRUH #	□	-38	-39	-41	-52	-58	-68	-71	-74	-65	-59	-43	-38

Figure 3. Monthly distribution of average first kilometer refractivity gradients (N-units/km) for Aswan, Helwan and Mersa Matruh. Also shown are results for Mersa Matruh in reference [4].

Location	N_o	Months with $N_o > 350$	Location	N_o	months with $N_o > 350$
1	332.1	2	25	329.3	-
2	338.6	4	26	331.3	1
3	337.7	3	27	326.2	-
4	338.3	4	28	334.7	3
5	339.6	4	29	336.2	3
6	342.5	4	30	328.3	-
7	341.3	4	31	327.3	-
8	340.6	4	32	323.6	-
9	342.9	4	33	335.4	2
10	343.3	5	34	325.6	-
11	344.5	5	35	328.8	1
12	344.6	5	36	328.7	-
13	327.0	-	37	332.6	1
14	337.1	3	38	323.7	-
15	336.9	4	39	325.7	-
16	326.2	-	40	320.1	-
17	329.0	-	41	323.2	-
18	321.1	-	42	313.8	-
19	338.3	3	43	309.3	-
20	335.6	3	44	294.1	-
21	336.8	3	45	313.3	-
22	335.7	3	46	313.4	-
23	330.4	1	47	300.8	-
24	334.8	2	48	304.4	-

Table 4. Annual average mean sea level refractivity N_o and the number of months the monthly average N_o exceeds 350 N-units.

	A	B
Mersa Matruh	0.617	0.013267
Mersa Matruh*	0.256	0.015889
Helwan	0.857	0.012559

Table 5. The A and B parameters of the exponential relation between N_s and ΔN. The * indicates results in reference [3].

the required heights. Due to the crudity of the approach, a difference not exceeding 20% was obtained when comparing the results with those of a previous investigation [4]. The parameters of the exponential relation between ΔN and N_s

$$\Delta N = - A.\exp(BxN_s) \quad (3)$$

are given in Table 5 for both Mersa Matruh and Helwan. The data for Aswan was not enough to give any meaningful results. These parameters can be used to calculate ΔN in the other locations of the corresponding regions and could give crude estimates for the other regions.

4. Conclusion

The relatively small errors obtained incalculating the refractivity from the monthly average values of meteorological data validates their use in cases where more detailed information is not available. This statement should be interpreted with more caution as far as the refractivity gradient is concerned. Nevertheless, the results show that no N_o pattern exists for all Egypt, since it includes regions of different climatic and topographic characteristics. As a general trend, N_s and its monthly spread decrease as we move southwards due to the increase in temperature and the decrease in humidity content.

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