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UPPER AIR TEMPERATURES IN EGYPT

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UPPER AIR TEMPERATURES IN EGYPT

BY E. V. NEWNHAM, B.Sc.

In the *Meteorological Magazine* for September, 1922, the observations of temperature and humidity made at Ismailiah (near the Suez Canal, about 70 miles north-east of Cairo) by No. 208 Squadron of the Royal Air Force during May, 1922, were discussed. It was observed that the rise of temperature immediately preceding the eastward passage of a depression across the eastern Mediterranean was most marked from the surface to a height of 5,000 ft. above mean sea level. At 12,000 ft. it was negligible. In two out of the three cases observed the rise appeared to be due to a cessation of the normal northerly winds, while in the other there was an actual northward flow of air from the interior. The lowest temperatures observed were attributed to the arrival of polar air from the extreme north of Europe.

Since May, 1922, further observations have been received from the same source, and later from No. 47 Squadron, stationed at Helwan. The present discussion refers to additional observations made at Ismailiah in June and August, 1922, and at Helwan from October, 1923, to April, 1924, so that, including May, 1922, all months except July and September are dealt with.

The mean values of temperature corresponding with pressures of 950, 900, etc., to 650 or 600 millibars, are shown in Table I. These means are taken throughout this discussion to be also the means corresponding with the average heights at which these pressures occurred, the error involved in such an assumption being small for a country where the variations of surface pressure are small.

In Table II. the difference between the mean temperatures for January and August are shown, these being the months with lowest and highest means at all heights. The figures give a rough idea of the seasonal variation, and some figures for south-east England have been added for the purpose of comparison. The range is seen to be rather greater at Cairo than in south-east England. It would, no doubt, be greater still were it not for the frequency of N.W. winds in the lower layers over Egypt in summer, which tend to prevent the temperature from becoming excessively high.

The most interesting facts about the temperature in the upper air in Egypt are, of course, not to be obtained from a table of this kind, but only by a detailed study of each individual set of observations in conjunction with the synoptic charts and observations of upper wind. To assist in such a study, isopleths of temperature and pressure were constructed for the whole

period. These isopleths showed that in the lower layers up to about 10,000 ft. during the autumn, winter and spring, heat waves occur from time to time, normally lasting several days, and that two or three such disturbances are usual in the course of a month. Examination of the synoptic charts showed that they are almost always associated with the approach of a depression to the eastern part of the Mediterranean.

It is natural to conclude that these rises of temperature are due to a northward flow of air, such as usually takes place in front of an advancing depression in north-west Europe. As has already been mentioned, the observations of upper wind at Cairo do not always show movements of this kind, yet there is certainly some correlation between the temperature and the direction of the wind at a height of about 3,300 ft., as was evident when a comparison was made between the wind direction corresponding with the highest and lowest temperature observed each month at this height. The lowest temperatures were generally with winds having at least some component from north, and often with nearly due north winds, while the directions corresponding with the highest temperature were very variable. At 12,000 and 14,000 ft., however, the fluctuations of temperature are much smaller, and do not appear to be correlated with the direction of the wind at those heights, nor do they correspond very closely with the fluctuations lower down (it is no uncommon event to have the temperature fall at 14,000 ft. while a big rise of temperature is taking place at 5,000 ft.). Thus on April 3rd, 1924, the temperature was 79° F. at about 5,000 ft., 19° above the mean for the month, and 32° at 14,000 ft., *i.e.*, only 1° above the mean. By the 6th it had fallen from 79° to 50° at 5,000 ft., and had actually risen to 36° at 14,000 ft. In October, 1923, there was a temperature of 72° at 5,000 ft. on the 6th, the maximum for the month at this height, associated with a reading of 29° (2° above the mean only) at 14,000 ft. On the 24th, a temperature at 5,000 ft. of only 49° was associated with one of 28° at 14,000 ft., *i.e.*, with a temperature slightly above the mean. In the case, however, of short and very pronounced "heat waves" in the lower layers, the temperature at 12,000 and 14,000 ft. often rises a few degrees. These facts form an interesting appendix to the already established fact that over Egypt it is the rule rather than the exception to find that at some level (generally between 5,000 and 10,000 ft.) the wind of the lower layers is more or less suddenly replaced by a totally distinct current, usually from a westerly direction, and frequently of considerable strength. Considerable rises of temperature that are confined to the lower layers only will tend to produce instability, but owing to lack of moisture they do not often give rise to thunderstorms in the north of Egypt. An exception occurred, however, on August 14th, 1922, when there was a storm near Ismailiah. On that day a temperature of 75° occurred at about 5,000 ft. at 7 a.m., the highest reported for this time of

the day and height during the month, while at 12,000 ft. the temperature was only 44°, the minimum for the month. Humidity was also high, particularly between 6,500 ft. and 10,000 ft., being exceeded at these levels only once during the month.

Vertical Temperature Gradients.—In a region where continental heat is tempered by breezes from a relatively cool sea, one would not expect to find very steep vertical gradients of temperature to be the rule. This is seen from Table III. to be the case up to about 6,000 ft., but from 10,000 to at least 12,000 ft., the mean gradient, although much below the dry adiabatic gradient, appears to differ little from the average for north-western Europe, being slightly over 3° per 1,000 ft. This rather steeper gradient occurs in the region where westerly winds predominate. The small gradient up to about 6,000 ft. is probably a phenomenon peculiar to the early hours of the morning, and would not have been found had the ascents been made at any other time of the day. On the whole, it seems that the gradients are steeper than might have been expected, and the very low rainfall of Lower Egypt must be due to lack of moisture rather than to stability of the air.

Relative Humidity.—The means for different pressures and heights are shown in Table IV. The mean is seen generally to decrease above 3,000 ft. at all times of the year, and reaches a minimum at a height varying between 5,000 and 10,000 ft. Higher up there is an increase which appears to be still in progress at 14,000 ft. Examination of individual cases shows that the relative humidity is frequently very low indeed in the dry zone, but that this zone is not always present. A careful comparison between the upper winds for the two types in the winter half of the year, October to March, showed that, as a general rule, the dry layer appears when winds from E. or NE. are replaced by Wly. winds higher up. Excellent examples occurred on January 5th, 1924, February 27th, 1924, and December 30th, 1923, and are given below :

Height (approx)	Jan. 5th, 1924		Feb. 27th, 1924		Dec. 30th, 1923	
	Wind	Humidity	Wind	Humidity	Wind	Humidity
ft.	mi/hr	%	mi/hr	%	mi/hr	%
14,200	NW 47	59	WNW 40	—	WSW 25	100
12,000	—	39	—	68	—	70
10,000	NNW 16	13	WNW 37	40	WSW 22	2
8,300	—	4	—	23	—	8
6,500 -	N 6	15	WNW 25	6	WSW 6	15
4,900 -	—	37	—	3	—	69
3,300 -	NNE 22	77	N 16	65	ENE 9	52
1,700 -	NNE 16	66	NE 22	69	E 16	59

A remarkable exception occurred, however, on October 25th, 1923, when a dry layer was associated with a wind which blew from NNE. at all levels from 1,700 to 14,200 ft.

The rarer cases where the humidity is comparatively steady up to 12,000 or 14,000 ft. occur with rather high humidities. The wind direction changes comparatively little, and is generally Nly. or Wly.

General Conclusions.—The observations made in the upper air in Egypt are an important addition to our knowledge of the general circulation of the atmosphere. It appears that there is a westerly current between 10,000 and 15,000 ft., in which the fluctuations of temperature from day to day are small, and in which the relative humidity normally increases with height, particularly in the winter. This current is strongest and steadiest in winter; it appears to be deformed without being interrupted by the passage of depressions across the eastern Mediterranean. This is, no doubt, the westerly current depicted by Teisserenc de Bort as extending right round the world in these latitudes at a height of 4 kilometres (13,000 ft.). Lower levels appear to be traversed by the wind currents of passing depressions. When air arrives from some easterly point it is often excessively dry, and may be nearly isothermal through a thickness of several thousand feet. In the summer the winds in the lower layers are very persistently Nly., and are, undoubtedly, part of the great circulation of air round the Asiatic centre of low pressure. The means given in this paper for the temperature and humidity corresponding with various pressures, must be regarded as very rough approximations only to true average conditions over Lower Egypt; some of the winter months, particularly November and December, had surface temperatures well above the normal, and it is probable that the means for all heights up to about 10,000 ft. are also high for these months. The following figures, taken from the monthly supplements to the Egyptian daily weather reports, show the actual departures from the normal in degrees Fahrenheit of the monthly mean surface temperatures for the Mediterranean section of Egypt for each of the months that have been discussed in this paper. They indicate which months are most likely to have had approximately normal temperatures in the upper air, although they cannot be used for computing the true normals at various heights :—

Month.	Jan. 1924	Feb. 1924	Mar. 1924	Apr. 1924	May 1922	June 1922	Aug. 1922	Oct. 1923	Nov. 1923	Dec. 1923
Departure from normal.	-0.4	+1.1	+1.4	+1.8	-0.4	+1.1	+1.8	-0.4	+3.2	+2.5

TABLE I.—MEAN TEMPERATURES IN DEGREES FAHRENHEIT
CORRESPONDING WITH VARIOUS PRESSURES AT ISMALIAH (1922)
AND HELWAN (1923-4).

The number of observations is shown in brackets beneath each mean value of the temperature. (There were no observations in July and September.)

Height*.	Pressure.	Jan. (1924).	Feb. (1924).	Mar. (1924).	Apr. (1924).	May (1922).	June (1922).	Aug. (1922).	Oct. (1923).	Nov. (1923).	Dec. (1923).
ft.	mb	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
16,500 -	550	-	-	-	-	-	-	-	16.5 (10)	21.6 (10)	19.3 (11)
14,200 -	600	18.0 (27)	18.7 (18)	20.0 (7)	30.9 (15)	—	—	—	26.8 (29)	28.4 (12)	23.8 (17)
12,000	650	23.2 (31)	25.8 (23)	29.0 (15)	35.8 (26)	34.4 (16)	42.9 (15)	48.6 (19)	33.2 (30)	34.3 (12)	29.3 (23)
10,000 -	700	29.1 (31)	32.4 (24)	34.9 (16)	43.2 (28)	42.4 (16)	49.6 (15)	54.5 (19)	41.3 (30)	40.0 (13)	34.8 (26)
8,000 -	750	32.7 (31)	37.7 (25)	39.4 (17)	50.0 (29)	50.0 (16)	55.5 (15)	59.3 (19)	47.2 (30)	44.5 (13)	38.9 (26)
6,500 -	800	36.2 (31)	42.3 (26)	42.7 (17)	56.3 (29)	56.6 (16)	61.7 (15)	64.5 (19)	52.5 (30)	49.5 (13)	42.6 (26)
4,900 -	850	40.0 (31)	46.8 (26)	46.1 (17)	60.2 (29)	61.3 (16)	66.7 (15)	67.8 (19)	56.9 (29)	54.0 (13)	45.3 (26)
3,300	900	44.8 (31)	49.9 (26)	47.9 (17)	62.4 (29)	65.2 (16)	69.4 (15)	71.8 (19)	62.1 (30)	59.4 (13)	50.8 (26)
1,700 -	950	49.2 (31)	52.7 (26)	51.4 (17)	64.1 (29)	67.7 (16)	71.3 (15)	74.5 (18)	66.8 (30)	61.7 (13)	54.9 (26)
Surface	-	48.3	53.6	58.3	63.4	75.0	80.7	81.3	66.5	65.2	55.4
Pressure at M.S.L.	-	1016	1016	1015	1015	1014	1011	1009	1016	1018	1018
Hour of Observation (local time).	-	5-6 a.m.	5 a.m.	5-5.30 a.m.	5 a.m.	6-7 a.m.	6-7 a.m.	6-7 a.m.	7-7.30 a.m.	7-9 a.m.	5-10 a.m.

* The heights are approximate, being the average heights at which the corresponding pressure occurred.

TABLE II.—APPROXIMATE ANNUAL RANGE OF MONTHLY MEAN
TEMPERATURE. (August minus January.)

Pressure	Approximate Height	Egypt	South-east England (for same heights)
mb.	ft.	° F.	° F.
650 -	12,000	25.4	—
700 -	10,000	25.4	20.3
750 -	8,300	26.6	—
800 -	6,500	28.3	—
850 -	4,900	27.8	21.8
900 -	3,300	27.0	—
950 -	1,700	25.3	—

TABLE III.—MEAN VERTICAL TEMPERATURE GRADIENTS.

Degrees Fahrenheit per 1,000 ft.

(There were no observations in July and September.)

Height	Jan. 1924	Feb. 1924	Mar. 1924	Apr. 1924	May 1922	June 1922	Aug. 1922	Oct. 1923	Nov. 1923	Dec. 1923
ft.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
14,000 -	2.2	3.4	4.2	2.0	-	-	-	3.8	3.0	2.3
12,000 -	3.2	3.2	3.6	3.0	4.0	3.0	2.7	3.0	3.0	2.9
10,000 -	2.5	3.2	2.8	4.0	4.4	3.2	2.7	3.8	3.0	2.6
8,000 -	2.5	2.7	2.3	3.8	3.9	3.2	2.7	3.2	2.8	2.3
6,000 -	2.7	2.5	2.1	3.0	1.0	3.2	2.5	2.9	3.0	1.9
4,000 -	3.2	2.0	1.3	1.6	2.6	1.5	2.5	1.5	3.5	2.4
2,000 -	2.8	1.9	2.3	1.1	1.3	1.1	1.7	2.9	1.1	2.7

TABLE IV.—MEAN RELATIVE HUMIDITIES.

The figures in brackets show the number of observations.

(There were no observations in July and September.)

*Height	Pres- sure	Jan. (1924)	Feb. (1924)	Mar. (1924)	Apr. (1924)	May (1922)	June (1922)	Aug. (1922)	Oct. (1923)	Nov. (1923)	Dec. (1923)
ft.	mb.	%	%	%	%	%	%	%	%	%	%
14,200 -	600	-	-	-	-	-	-	-	75 (24)	72 (12)	82 (15)
12,000 -	650	62 (24)	55 (18)	62 (19)	40 (29)	52 (16)	28 (14)	27 (18)	60 (29)	56 (12)	73 (20)
10,000 -	700	57 (30)	48 (22)	48 (20)	23 (29)	42 (16)	26 (14)	28 (19)	45 (29)	43 (13)	59 (23)
8,300 -	750	53 (30)	53 (25)	38 (20)	19 (29)	36 (16)	23 (15)	29 (18)	49 (30)	48 (13)	54 (23)
6,500 -	800	58 (30)	55 (26)	42 (21)	21 (29)	36 (16)	29 (15)	27 (19)	52 (30)	57 (13)	60 (24)
4,900 -	850	73 (31)	61 (26)	48 (20)	25 (25)	33 (16)	30 (15)	42 (19)	57 (29)	62 (13)	68 (25)
3,300 -	900	77 (31)	67 (25)	56 (19)	34 (27)	45 (16)	41 (15)	53 (19)	61 (30)	65 (13)	73 (25)
1,700 -	950	74 (31)	78 (26)	66 (19)	47 (26)	60 (16)	59 (15)	68 (19)	70 (29)	75 (12)	73 (24)

* Approximate only, being the average height at which the corresponding pressure occurred.

