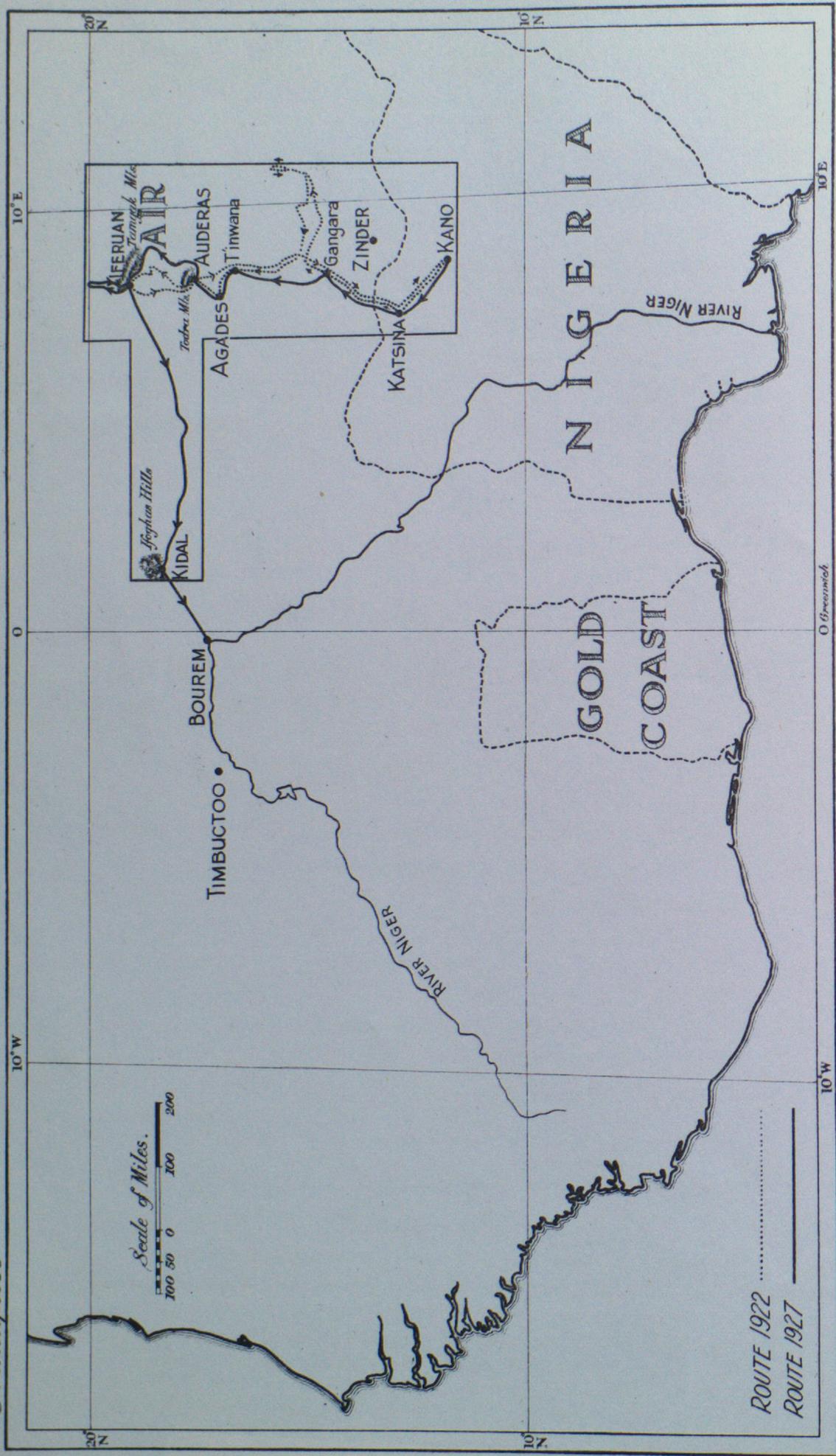


Frontispiece



WEST AFRICA, Showing Routes in 1922 & 1927

METEOROLOGICAL OFFICE

GEOPHYSICAL MEMOIRS No. 48
(Eighth Number of Volume V)

The Meteorological Results
of
Journeys in the Southern Sahara, 1922 and 1927

Made by
Francis Rennell Rodd, F.R.G.S.

Discussed by
C. E. P. Brooks, D.Sc., and S. T. A. Mirrlees, M.A.

Published by Authority of the Meteorological Committee

[CROWN COPYRIGHT RESERVED.]



LONDON :
PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
To be purchased directly from H.M. STATIONERY OFFICE at the following addresses :
Adastral House, Kingsway, London, W.C.2 ; 120, George Street, Edinburgh ;
York Street, Manchester ; 1, St. Andrew's Crescent, Cardiff ;
15, Donegall Square West, Belfast ;
or through any Bookseller.

1929

Price 3s. 6d. Net.

TABLE OF CONTENTS

	PAGE
GEOGRAPHICAL INTRODUCTION BY F. R. RODD	3
DISCUSSION OF THE METEOROLOGICAL RESULTS BY C. E. P. BROOKS AND S. T. A. MIRRLEES	
SERIES I.	
1. THE GENERAL CLIMATE OF THE SOUTHERN SAHARA	6
2. THE INSTRUMENTAL EQUIPMENT AND THE METHODS OF OBSERVATION	7
3. BAROMETRIC PRESSURE	9
4. TEMPERATURE	11
5. HUMIDITY	19
6. WINDS	22
7. AMOUNT AND TYPE OF CLOUD	24
8. RAIN AND OTHER PHENOMENA	26
9. VISIBILITY	30

LIST OF ILLUSTRATIONS

Frontispiece—WEST AFRICA, SHOWING ROUTES IN 1922 AND 1927

FIGURE

1. DIURNAL INEQUALITY OF PRESSURE, 1927	10
2. DIURNAL INEQUALITY OF TEMPERATURE, 1927	15
3. DIURNAL VARIATION OF TEMPERATURE ON "QUIET" AND "DISTURBED" DAYS, JULY TO SEPTEMBER, 1927	18
4. SERIES OF READINGS ON TWO DAYS IN SEPTEMBER, 1922	21
5. DIURNAL INEQUALITIES OF PRESSURE, "QUIET" AND "DISTURBED" DAYS, AUGUST, 1927	28
6. WIND, TEMPERATURE AND PRESSURE ON SELECTED DAYS IN 1927	28 <i>facing</i>

THE METEOROLOGICAL RESULTS OF JOURNEYS IN THE SOUTHERN SAHARA, 1922 and 1927 made by Francis Rennell Rodd

GEOGRAPHICAL INTRODUCTION

This *Memoir* is a study of the meteorological data collected in the south central Sahara in 1922 and 1927. Full geographical accounts of these two expeditions have appeared in the *Journal of the Royal Geographical Society*, Volume LXXIII, Nos. 1 and 2 (January and February, 1929), and in previous numbers, notably August, 1923. Detailed maps of the areas in which I travelled were published in the last two numbers. Other more general maps are referred to on the sheets published by the Royal Geographical Society; in addition to these the French 1/1,000,000 Croquis du Sahara (on the projection and arrangement of the International Million map) may be consulted. The latter and the R.G.S. sheets use the Greenwich meridian which is also referred to throughout this *Memoir* where longitudes are given: most of the other French maps use the meridian of Paris which is 2° 20' 14" east of Greenwich. Times in this *Memoir* are in Greenwich mean time, and temperatures in °F.

No determinations of height by levelling in the areas I visited have been made except at Kano, the head of the railway from the coast at Lagos. I have made some calculations of heights above mean sea level using boiling-point data and sea-level isobars and isotherms¹: the results accord reasonably well with the conclusions of French surveyors in the area in various years before the war. The following table gives some of the results for certain places mentioned in this *Memoir*:—

	Heights above mean sea level	
	Rodd.	French results.
	ft.	m.
Katsina Rest House	1,660	—
Gangara Rest House	2,057	—
T'inwana	2,218	—
Auderas Camp	2,641 (=805 m.)	798 (Foureau).
Tegidda Mellen	2,150 (=655 m.)	700 (Foureau).
Tanekert	1,205 (=367 m.)	386 (Meunier map).

The French have recently established, or perhaps re-established since the war, a meteorological station at Agades in Air, equipped with thermometers and rain-gauge, but without a barometer. A meteorological station has also been working for some years at Kidal in the Ifoghas Mountains where some recording instruments are kept. Daily instrumental readings at these stations are now sent by W/T. to Dakar, French West Africa, and will perhaps in future be available for research.

Both the 1922 and 1927 expeditions started from Kano in northern Nigeria and used camel transport. The first journey also ended at Kano: the second journey finished on the Niger near Timbuctoo. On my way north in 1922 I visited a small detached massif in the desert south-east of Air in lat. 16° 4' N., long. 11° E.: the rest of the journey was made to, from, and in, Air which lies in the rectangle between lat. 16° 30' and 19° 30' N., long. 7° 30' and 9° 30' E. In 1927 Air was again visited as far north as lat. 20° but instead of returning to Nigeria the expedition marched west, roughly between lat. 17° 30' and 18° 30' as far as Kidal in long. 1° 21' E. From there the expedition descended to the Niger and returned to England via Timbuctoo, Bamako and Dakar. This *Memoir* deals with climatic conditions in Air and the neighbouring districts.

A full account of the physical features of the country is contained in my book "People of the Veil" (MacMillan 1926). The following description is a brief note on the regions visited and their configuration.

¹ From *London, Q.J.R. Meteor. Soc.* 43 p. 182 and 44 p. 191.

The belt of cultivated land and park bush in north Nigeria 1,500–1,700 ft. above the sea gives place on the Anglo-French boundary to a belt of dense bush of characteristically equatorial type; in certain cleared areas millet and guinea corn are grown. This belt of bush continues progressively to lose its equatorial, and acquire a Saharan, character as the desert is approached. The ground is sandy and undulating without any marked relief. There are low hills in Gure and some rock outcrop in Elakkos where considerable quantities of millet are produced (lat. 14° N., long. 9° 30' E.) but these physical features have no climatic importance. A deep belt of uninhabited thorn bush separates Elakkos from the desert which begins in lat. 15° 15'. Further west, however, that is to say due south of Air, the belt of bush gives place to an area of open grass-covered steppe with a gently undulating surface (1,600–1,700 ft.) scarcely broken by a few scattered low hills (2,500 ft.). This country, called Damergu, was formerly the granary of Air and the district to the south. Grain cultivation has decreased during the last 10 years, owing to depopulation principally connected with political events, but is still considerable.

Damergu is surrounded on all sides by thorn bush. The belt on the northern side is more stunted and thorny than to the south, and nearly 60 miles deep. The open desert is reached south of Air only in lat. 16°. The desert, steppe-desert in reality as it carries a tenuous covering of hardy plants and an occasional small tree, lies about 1,600 ft. above the sea. The wide shallow valleys flow west but show no beds or traces of flowing water for more than short discontinuous stretches. The depressions seem to be the product of longitudinal dune formations with a general north-east to south-west orientation but are not very regular and contain many small closed basins. Local precipitation is all absorbed: pools form after the rains and survive a few weeks. For the rest of the year water is obtained from deep wells in the valley bottoms.

The first rock out-crop of importance is the low sandstone massif (summits about 3,000 ft.) of Tinwana-Eghalgawen with a line of cliff (1,500–1,600 ft.) east and west of it. These hills and cliff form the southern bank of the River of Agades, a wide alluvial plain receiving many affluents from the Air Mountains to the north and draining all the precipitation of south Air westwards, eventually into a series of wide connected basins which belong to the Niger hydrographic system.

From the bottom of the River of Agades some 1,400 ft. above the sea emerge the foothills of the Air plateau. The ground rises by a series of steps to 2,700 ft. in central Air. Through this Archean plateau at various points have been thrust a number of volcanic massifs whose peaks attain heights of 6,000 ft. and more above the sea. The principal large mountain groups here are Taruaji in south-east Air and the Bagezan Plateau, Todra, Dogam and Bila in central Air.

Auderas lies under the slopes of the Todra and Dogam groups in a valley on the plateau 2,450 ft. above the sea and west of the central massifs. On the opposite side of the latter the plateau, 2,800–3,000 ft. high, slopes gradually away to the eastern desert which stretches without any break of importance as far as the Tibesti Mountains. Mount Todra above Auderas is about 6,000 ft. above the sea. The valleys of the Bagezan plateau are some 4,000 ft. high with surrounding peaks probably a little over 6,000 ft.

North of the mountains in central Air is a rocky area broken by smaller isolated groups of mountains. Levels decline several hundred feet from the high step of the central plateau to the great westward-flowing valleys which drain north-east and north Air. Beyond them lies a fringe of high mountains enclosing north-east Air and separating the country from the desert into which they disappear rather suddenly. The mountains attain some considerable depth in the Tamgak massif rising to a height of over 6000 ft. above the sea from the plain at their western and south-western bases 2,000 ft. high. (Iferuan on the Ighazar plain is about 2,100 ft. above the sea.)

Precipitation is heaviest in Air, in every case west and south of the massifs. The larger valleys are all westward flowing; Air as a whole seems to lie definitely and wholly in the Niger basin; it does not form the watershed between the Niger and the Lake Chad or the Kawar basins.

North of Tamgak in the area called Fade the mountains are lower, exist in isolated masses and occupy a narrowing belt of country hemmed in between the eastern and western deserts. The level of the valley beds rises again to some 2,600 feet at Tarazit where a relatively small but high group of mountains called Grebun appears responsible for the fairly ample local rainfall. Between Grebun and Tamgak the hills are too low to have much effect on precipitation at this northern edge of the summer rain belt. Pastures and water therefore are exceedingly seasonal and unreliable in the area.

On the western side the Air plateau throughout its length slopes gently away until the last rocks disappear below the sea of sand which is the western desert. This area over 300 miles broad as far as the Ifoghas Mountains is flat and exceedingly bare. Such rock outcrop as occurs is very inconspicuous. The northern part is absolutely barren gravel desert, the southern part merges gradually and imperceptibly into equatorial bush land. The desert is at its lowest in about lat. $17^{\circ} 20'$ N. where a long east and west depression collects the drainage from Air and the Ahaggar system by a series of scarcely perceptible broad valleys without beds of flow but having some underground water, as is proved by the wells at points along their course.

This depression or "belly of the desert," called Assakarai, trends gently west and south towards the Niger bend taking the name of Azawad or Azawaq.

On the northern boundary of this immense and barren waste are the arid foothills of Ahaggar; the western side is marked by the low boulder-strewn ridges which are called the Ifoghas Mountains, themselves scarcely worth dignifying by such a name. They are, in fact, a long south-westerly spur of the Ahaggar plateau. The drainage of the Ifoghas Mountains is generally south-west and west: the precipitation appears to be smaller than in Air, nor are the valleys subjected to such great or violent floods.

The western desert north of the bush belt carries some scattered desert vegetation wherever showers fall but their distribution is irregular and pasture consequently unreliable. The northern part is as a whole virtually pastureless.

In Air the vegetation is confined to the valleys where along the banks there are often substantial trees and dôm palm (*Hyphene*) forests. In a few favoured districts, where water survives in the sand, there are date-palm plantations and small gardens wholly dependent on shallow well irrigation. The trees are mostly of the *Acacia* variety. Some of these, and especially some *Balanites Aegyptiaca*, grow to large size with trunks up to 3 ft. and 3 ft. 6 in. in diameter. Local desiccation appears to be going on in eastern Air where there are few young trees and many of the older ones are dying. In western Air, on the other hand, rainfall appears now to be greater than before, which is one of several reasons why nomad tribes formerly dwelling in eastern Air during the last twenty years have moved to the other side.

According to local tradition Air appears to be at the end of a phase of decreased rainfall which has now lasted about 14 years.

This is not the place to discuss Saharan desiccation but it may be worth recording my view which agrees with that of certain French authorities. That some desiccation is occurring is undeniable: certain local areas on the contrary are apparently better favoured now than last century. There is no evidence that climatic conditions have changed materially for some ages past if apparent changes involving lesser local rainfall are examined in the light of wider evidence, including native tradition. There are, however, good grounds for believing that desiccation attributable to mechanical causes is in progress by such agencies as sand deposit and dune formation, desertion of cultivated areas, silting up and oblivion of old wells, progressive modification of the physical features by erosion, and silting of valleys, human modification of areas by the destruction of vegetation, etc., etc. It is also probable that a secular loss of local humidity is consequently in progress which is gradually affecting local climatic conditions though not in the manner or to the degree which are generally supposed by casual travellers.

DISCUSSION OF THE METEOROLOGICAL RESULTS

§I—THE GENERAL CLIMATE OF THE SOUTHERN SAHARA

The two expeditions of 1922 and 1927 covered nearly the same ground, between about 12° to 20° N. latitude and 0° to 11° E. longitude, including the extreme northern part of the northern Provinces of Nigeria and the southern part of the French Sahara in those administrative districts known as the *Colonie au Niger* and the *Soudan Français*. This region has a very interesting climate of the monsoon type, and fortunately the expeditions included parts of both monsoons. The year is divided into a long dry season in the winter half year, with north-easterly winds (the "Harmattan" of the Guinea coast), very clear skies and a practically complete absence of rain, and a summer season with south-westerly winds, more cloudy skies and more or less rain. At Kano in latitude 12° N. the rainy season begins in May, at Zinder, 14° N., in June, and in Air, about 18° N., in July.

The mean annual rainfall at Kano in latitude 12° N. is 34 inches, and from here northward the amount decreases. At Zinder (13° 47' N.) the average is 20 inches, three quarters of which falls in the months of July and August. Still further north the rainfall becomes very irregular and beyond about latitude 15° the average fall is less than 10 inches a year. The amounts are however greatly influenced by the topography, and actually much more rain falls in the mountainous Air region between 17° and 19° N. latitude than over the lower ground to the southward², between 15° and 17°. Similarly there is an area of relatively heavy rainfall further west, in the mountains of Ifoghas, in latitude 16° to 18° N., but between these two areas of high ground the rainfall is negligible, probably less than five inches a year. Monthly normals³ for Kano and Zinder are as follows:—

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
Kano .. (1905-27)	0·01	0·05	0·09	0·48	2·40	4·55	7·99	11·95	5·59	0·42	0·00	0·02	33·55
Zinder .. (1905-9; '11; '14)	0·00	0·00	0·01	0·09	0·32	1·27	5·40	9·64	2·92	0·04	0·00	0·00	19·69

The north-easterly winds are associated with a low relative humidity and a large daily range of temperature, so that while the days may be very hot, the nights are cool. During the period of south-westerly winds the humidity is much greater; the day temperatures are not so high but the nights are warm and oppressive. The following average data for Kano illustrate the annual variation in these respects.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Mean daily max. tem- perature °F.	85·3	90·7	98·7	103·2	100·6	94·7	88·8	86·0	89·7	94·7	93·4	87·0	92·7
Mean daily min. tem- perature °F.	53·7	57·7	64·6	73·2	74·9	72·7	70·4	69·7	70·6	66·5	59·3	54·3	65·6
Relative humidity % at 9h. ..	35	31	32	41	50	63	73	71	71	54	35	34	50

² I should say that Auderas probably received some 8 in. rain (in 1927): and that village was very badly favoured (unusually badly even compared with 1922). I am convinced by the vegetation I saw that the country 10 miles east and 10 miles north received much more rain, probably not less than 12 in., which is probably normal for central Air though the last few years have been notorious for very *irregular* distribution. A very slight modification from one year to another in the prevalent winds would have a large local effect in central Air owing to the shape of the mountainous reliefs. F. R.

³ Prepared in the Meteorological Office.

The south-westerly current of the summer monsoon is shallow, probably only about 1,000 metres in thickness, and is overlain by easterly winds. At times during the occurrence of rainstorms these easterly winds break through and reach the surface. An interesting feature of the inter-action between these north-easterly and south-westerly winds is the occurrence of tornadoes, of which a few instances are noted in the records.

§2—THE INSTRUMENTAL EQUIPMENT AND THE METHODS OF OBSERVATION

For both expeditions meteorological instruments were lent by the Royal Geographical Society, some of the instruments which were used in 1922 being used again in 1927.

The following is a list of the instruments :—

1922	1927
Dry and wet bulb set.	Whirling hygrometer.
2 maximum and minimum sets.	3 maximum and minimum sets.
Thermometer for water temperatures.	Thermometer for water temperatures.
4 sling thermometers.	3 sling thermometers.
2 boiling-point thermometers.	3 boiling-point thermometers.
4 aneroid barometers.	4 aneroid barometers.
	Barograph.
	Thermograph.
	Rain-gauge.
	Air meter.

Certain of the instruments were adopted as standards and others regarded as spares, but a considerable number of simultaneous readings were made so as to provide a good overlap in case of accident to a standard instrument. Instrumental corrections were not applied at the time of reading.

The method of exposure usually adopted was to hang the instruments in a hut or tent or in a shelter, so that free access of air was permitted, but any access of direct solar radiation prevented. On occasion the barograph and thermograph were placed in a doorway or on a rock ledge.

In 1922 after it was suspected that the readings might have been affected by direct radiation, a ventilated box was constructed, in which the dry and wet bulbs were exposed. This box was placed 3 ft. 6 in. to 4 ft. 6 in. from the ground, had no back or post and was hung from the eaves of a hut in a draught near the doorway or in the shade of some shelter made for the purpose, where no sun could reach it. After this box was brought into use the readings appeared more consistent, such differences as occurred being due to radiation from the walls of the hut and not to insufficient ventilation. Owing to this exposure, the special method of working up the humidity values described on page 19 was adopted.

In 1927 the maximum and minimum thermometers as well as a dry and wet bulb set were mounted on a specially constructed instrument board. The published readings of the dry-bulb and humidity were obtained from the whirling hygrometer, and as it was considered that the ventilation in this case was sufficient, no special procedure was adopted and the humidity values were worked out by the Hygrometrical Tables⁴ of the Meteorological Office.

At Auderas, where the expedition camped from July 25 to the end of August, 1927, the instruments were hung up in a tree under a shelter composed of two canvas sunproof roof covers, with loosely hanging sides, the back and front being open, and a floor constructed of sticks and ropes. In 1922 when the expedition was also at Auderas from August 10 to September 5 a similar arrangement was adopted.

⁴ M.O. Publication 265, 1924.

The main observation hours adopted were 6h. and 18h. G.M.T. At these hours, or as near as circumstances permitted, the barometers and thermometers were read, while wind direction and force, weather, state of sky and occasionally, visibility were noted.

During 1927, when camp was pitched for a single night the minimum thermometer was set up in the evening and read next morning; and if the halt extended over the day the maximum thermometer also was set up and read in the evening. Thus in most months the number of minimum exceeded the number of maximum readings.

In 1922 the same procedure was observed when possible, but march was at times resumed early in the morning before the normal time of occurrence of the minimum temperature; it was then usually possible to set the maximum thermometer, camp being pitched about mid-day and the time of maximum temperature being usually later than this.

Besides the regular morning and evening observations a number of observations were made at intermediate hours. Amongst these were a few sets of hourly observations, required in connexion with height determinations. In 1927 the rain-gauge was set up occasionally; a few measurements of wind velocity were made with the air meter, and several sets of autographic records were obtained including a complete month's record in August.

TABLE I.—DIURNAL INEQUALITY OF

Station	Lat. N.	Long. E.	Dates	Hours								
				0	1	2	3	4	5	6	7	8
Katsina ..	13 0	7 38	May 23-28	+ 5	+ 2	0	0	+ 2	+ 6	+10	+15	+19
Gangara ..	14 36	8 30	June 13-16	+ 4	+ 3	0	- 1	0	+ 4	+12	+21	+24
Tinwana ..	16 42	8 27	July 5-9	+ 7	+ 6	+ 5	+ 4	+ 7	+11	+15	+21	+25
Anderas ..	17 38	8 25	July 26-31	+ 8	+ 8	+ 9	+ 9	+10	+12	+16	+21	+24
Anderas ..	17 38	8 25	Aug. 1-31	+ 8	+ 7	+ 4	+ 4	+ 5	+ 6	+ 9	+11	+12
Heruan ..	19 5	8 25	Sept. 22-28	+14	+13	+11	+ 9	+10	+14	+17	+18	+17
Various stations	18 20	5 40	Nov. 8-9, 15-16, 27-28	+ 6	+ 4	+ 3	+ 4	+ 4	+ 3	+ 5	+ 7	+ 8
Mean			May to Sept.	+ 8	+ 7	+ 5	+ 4	+ 6	+ 8	+11	+15	+16

The scales of the barograph and thermograph charts were as follows:—

Barogram pressure scale	1 mercury inch	=	1 inch on sheet.
„ time scale	24 hours	=	10.8 in.
Thermogram temperature scale	100°	=	3.2 in.
„ time scale	24 hours	=	10.6 in.

Both clock drums revolved once in about 24 hours, but showed variations of rate with temperature change, losing slightly during the day and gaining slightly during the night. This effect was more marked in the barograph clock.

In tabulating the autographic records it was assumed that the clock rates had been uniform between the time marks, which were generally made at 6h. and 18h. G.M.T., at least, and on several days at intermediate times as well; by means of a scale on transparent paper the hours between the time marks were marked off on each chart, taking account of all the time marks.

The temperature curves were controlled by the readings of the sling thermometer only, the differences being more consistent than the differences between the extreme readings on the curves and the maximum and minimum thermometer readings.

§ 3—BAROMETRIC PRESSURE

The distribution of barometric pressure over West Africa undergoes a considerable seasonal change. According to the maps compiled by Col. Sir Henry Lyons⁵ the distribution in winter shows an area of high pressure over the north-western Sahara, and a trough of low pressure over equatorial Africa, the whole region between being occupied by a belt of steady north-easterly winds. In summer the high pressure area moves north-westward over the Atlantic, and the low pressure trough moves northward to a position between about latitudes 15° and 20° N. South of latitude 15° the prevailing winds at this season are south-westerly, while within the trough the winds are variable.

It has been considered that no useful purpose would be served by the full discussion of the daily observations of pressure, as such, obtained during Mr. Rodd's two expeditions. The sites of observation were constantly changing, and the

PRESSURE IN 1927 (UNIT 0·1 MB.).

(G.M.T.).														Stations	
9	10	11	12	13	14	15	16	17	18	19	20	21	22		23
+21	+17	+10	+ 2	- 5	-12	-16	-19	-22	-21	-15	- 9	- 1	+ 4	+ 7	Katsina.
+23	+19	+13	+ 5	- 2	- 9	-15	-21	-24	-23	-21	-14	- 4	+ 1	+ 4	Gangara.
+22	+18	+11	+ 1	-10	-19	-22	-23	-27	-27	-20	-12	- 5	+ 2	+ 7	Tinwana.
+23	+19	+11	+ 2	- 7	-16	-25	-32	-34	-30	-21	-13	- 3	+ 4	+ 6	Auderas.
+12	+ 9	+ 5	- 2	- 9	-14	-17	-19	-18	-14	- 9	- 5	+ 1	+ 5	+ 7	Auderas.
+13	+ 7	- 2	-13	-24	-31	-31	-28	-24	-18	-10	- 1	+ 8	+13	+15	Iferuan.
+12	+15	+10	0	-12	-19	-21	-20	-15	- 8	- 4	+ 1	+ 5	+ 8	+ 7	Various stations.
+16	+12	+ 6	- 2	-10	-16	-20	-22	-22	-19	-13	- 7	0	+ 5	+ 8	Mean.

observations of pressure were in fact fully utilised for the determinations of height above mean sea level. It is only when camp was fixed at one site for some weeks or where a series of observations were made at brief intervals, that the pressure readings are of meteorological interest, and these readings are set out in Tables III and IV.

Variations of pressure.—In 1927 Mr. Rodd carried an aneroid barograph with his other instruments, and when camp was fixed at one spot for some time, he obtained valuable series of barograms. These are summarised in Table I, and in Fig. 1. All the curves in the latter show a principal maximum in the morning hours, about 8h. or 9h. G.M.T., and a principal minimum in the afternoon, at 16h. or 17h. There is also a small secondary maximum about midnight and a secondary minimum about 3h., but these do little to modify the 24-hour pressure wave. The average daily range of pressure is about 4 mb.

⁵ London, *Q.J.R. Meteor. Soc.*, 43, 1917, pp. 113-150.

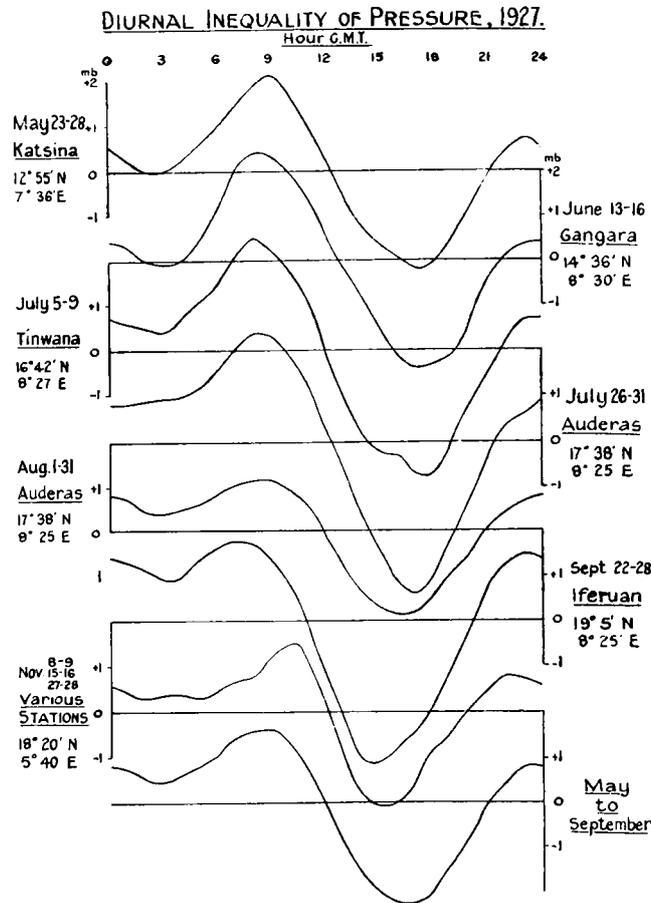


FIG. 1.

The figures were analysed by means of the harmonic series:—

$$\Delta P = a_1 \sin(t + \theta_1) + a_2 \sin(2t + \theta_2) + a_3 \sin(3t + \theta_3)$$

the amplitudes being expressed in millibars, and the phase angles reduced to local mean time⁶. The values are shown in Table II.

TABLE II—CONSTANTS OF DIURNAL VARIATION OF PRESSURE

	a_1	θ_1	a_2	θ_2	a_3	θ_3
	mb.	°	mb.	°	mb.	°
May-June	1.5	356	1.0	157	0.3	120
July	2.2	6	1.1	150	0.1	132
August	1.2	20	1.0	156	0.1	79
September	2.2	37	1.1	174	0.1	86
November	1.1	28	1.0	166	0.3	337
May - September	1.5	15	1.0	156	0.1	100

The diurnal wave is large but this is a natural result of the large diurnal variation of temperature and the continental position. The phase agrees closely with the phases found at other continental stations⁷, and it seems that the instrumental temperature effect, if any, must be very small.

⁶ Air being in about longitude 8° 30' E., local time is about 34 minutes ahead of G.M.T.

⁷ Hann, J. v. Die ganztägige (24-stündige) Luftdruckschwankung in ihrer Abhängigkeit von der Unterlage (Ozean, Bodengestadt. *Wien, Sitz Ber. Ak. Wiss.*, IIa, 128, 1910, p. 413.

The twelve-hourly oscillation shows a remarkable constancy of amplitude, even extending to November, for which only three days' curves are available. Although the morning minimum is almost eliminated by the 24-hour oscillation, to an extent unusual in the tropics, both amplitude and phase accord well with the results obtained by G. C. Simpson⁸. Even the eight-hourly oscillation, in spite of its small amplitude and apparent variability of phase, agrees excellently with Hann's results⁹.

In 1922 no autographic instruments were carried. Eye readings were made at frequent intervals on a few days, but these were insufficient for the determination of harmonic constants. The readings of pressure are shown in Table III, and are illustrated, with the corresponding readings of temperature and humidity, in Fig. 4.

TABLE III—DIURNAL VARIATION OF PRESSURE SHOWN BY SERIES OF READINGS ON DAYS IN 1922

Hour G.M.T.		06.30	7	8	9	10	11'	12	13	14	15	16	17	18	19	20	21	22
SEPT. 9. Auderas—17° 38' N. 8° 25' E.																		
in.	27.00+	.26	—	.29	.30	.28	.28	—	.22	.21	.20	.20	.20	.21				
mb.	920+	3.1	—	4.1	4.5	3.8	3.8	—	1.8	1.4	1.1	1.1	1.1	1.4				
SEPT. 24. Auderas—																		
in.	27.00+	.32	—	.36	.36	.36	.35	.33	—	.28	.27	.27	.26	.25	.27	.30	.30	.32
mb.	920+	5.2	—	6.5	6.5	6.5	6.2	5.5	—	3.8	3.5	3.5	3.1	2.8	3.5	4.5	4.5	5.2

Irregular variations of pressure, of the order of a few hours or days in length, are generally small compared with the diurnal variation. Day-to-day changes could only be studied when camp was fixed at the same place for a period of ten days or more. The daily readings on these occasions are shown in Table IV. The average change of pressure from 6h. or 18h. on one day to the same hour on the next, irrespective of sign, was calculated for certain of these occasions. The results gave :—

- 1922 : April 11–28, Fanisau, 6h. 0.8 mb.; 18h. 1.1 mb.
- August 10–20, 24–31, Auderas, 6h. 1.4 mb.; 18h. 1.6 mb.
- September 1–5, 8–30, Auderas, 6h. 0.6 mb.; 18h. 1.0 mb.
- 1927 : August 1–31, Auderas, 6h. 1.5 mb.; 18h. 1.6 mb.
- October 1–21, Tegidda Mellen, 6h. 0.9 mb.; 18h. 0.9 mb.

The general average, 1.2 mb., is little more than a quarter of the average range of pressure on any one day. For comparison it may be remarked that near Iceland the average change of pressure from one day to the next is 8–10 mb. From observations at stations in French West Africa it appears that this small variation of pressure from one day to another is true of most Saharan stations.

§ 4—TEMPERATURE

Satisfactory observations of temperature on an expedition are naturally more difficult than at a fixed station where a screen can be installed in a suitable site. In 1922 Mr. Rodd carried ordinary dry and wet bulb and self-registering maximum and minimum thermometers, and also sling thermometers. Early in this expedition he realised that the exposures of his ordinary thermometers—in doorways, verandahs, etc.—were not always satisfactory, since they frequently read considerably higher than the sling thermometers owing to insufficient protection from radiation. On May 12 he accordingly constructed a ventilated box, described on p. 7, and from that date onwards the readings were more consistent. In 1927 he carried a whirling hygrometer.

⁸ The twelve-hourly barometer oscillation. *London, Q.J.R. Meteor. Soc.*, 44, 1918, p. 16.
⁹ *Meteor. Zs.*, 34, 1917, p. 185.

TABLE IV—PRESSURE READINGS BY

FANISAU. 12° 5' N. 8° 33' E.			DANKABA. 13° 13' N. 7° 45' E.			AUDERAS. 17° 38' N. 8° 25' E.			AUDERAS.		
Date	Morning	Evening	Date	Morning	Evening	Date	Morning	Evening	Date	Morning	Evening
1922.	in.	in.	1922.	in.	in.	1922.	in.	in.	1922.	in.	in.
April 11 ..	29·38	29·30	May 8 ..	—	29·35	August 10 ..	—	27·14	Sept. 7 ..	—	27·12
12 ..	29·39	29·27	9 ..	29·46	29·38	11 ..	27·22	27·17	8 ..	27·25	27·20
13 ..	29·35	29·25	10 ..	29·45	29·37	12 ..	27·23	27·16	9 ..	27·26	27·21
14 ..	29·35	29·25	11 ..	29·45	29·43	13 ..	27·18	27·13	10 ..	27·25	—
15 ..	29·38	29·26	12 ..	29·50	29·45	14 ..	27·22	27·18	11 ..	—	27·25
16 ..	29·38	29·27	13 ..	29·51	29·43	15 ..	27·28	27·22	12 ..	27·33	27·30
17 ..	29·38	29·23	14 ..	29·50	29·42	16 ..	27·25	27·18	13 ..	27·24	27·20
18 ..	29·38	29·27	15 ..	29·46	29·34	17 ..	27·20	27·14	14 ..	27·27	27·24
19 ..	29·37	29·35	16 ..	29·43	29·36	18 ..	27·23	27·20	15 ..	27·29	27·22
20 ..	29·35	29·22	17 ..	29·44	29·34	19 ..	27·27	27·27	16 ..	27·27	27·20
21 ..	29·30	29·24	18 ..	29·42	—	20 ..	27·31	27·21	17 ..	27·26	27·22
22 ..	29·34	29·26				21 ..	27·24	—	18 ..	27·25	27·18
23 ..	29·34	29·21				23 ..	—	27·11	19 ..	27·28	27·23
24 ..	—	29·22				24 ..	27·20	27·09	20 ..	27·28	27·24
25 ..	29·32	29·22				25 ..	27·16	27·12	21 ..	27·28	27·20
26 ..	29·31	29·20				26 ..	27·24	27·23	22 ..	27·30	27·26
27 ..	—	29·23				27 ..	27·28	27·26	23 ..	27·30	27·29
						28 ..	27·24	27·19	24 ..	27·32	27·25
						29 ..	27·19	27·12	25 ..	27·35	27·26
						30 ..	27·22	27·18	26 ..	27·28	27·23
						Sept. 31 ..	27·26	27·18	27 ..	27·28	27·23
						1 ..	27·22	27·18	28 ..	27·28	27·23
						2 ..	27·24	27·18	29 ..	27·30	27·20
						3 ..	27·24	27·24	October 30 ..	27·30	27·22
						4 ..	27·25	27·23	1 ..	27·26	27·16
						5 ..	27·26	—	2 ..	27·25	27·18
									3 ..	27·23	27·24
									4 ..	27·16	—

ANEROID AT VARIOUS STATIONS

AUDERAS. 17° 38' N. 8° 25' E.			AUDERAS.			AUDERAS.			TEGIDDA MELLEN. 19° 12' N. 8° 21' E.		
Date	Morning	Evening	Date	Morning	Evening	Date	Morning	Evening	Date	Morning	Evening
1927.	in.	in.	1927.	in.	in.	1927.	in.	in.	1927.	in.	in.
July 24 ..	—	27·05	August 8 ..	27·13	27·07	August 23 ..	27·14	27·10	Sept. 30 ..	—	27·44
25 ..	27·11	26·95	9 ..	27·19	27·10	24 ..	27·18	27·07	Oct. 1 ..	27·52	27·49
26 ..	27·10	26·95	10 ..	27·12	27·06	25 ..	27·10	27·08	2 ..	27·54	27·45
27 ..	27·11	26·91	11 ..	27·08	27·02	26 ..	27·09	27·04	3 ..	27·50	27·44
28 ..	27·04	26·91	12 ..	27·10	26·99	27 ..	27·05	27·04	4 ..	27·53	27·46
29 ..	27·02	26·97	13 ..	27·10	27·06	28 ..	27·05	27·09	5 ..	27·50	27·43
30 ..	27·13	27·01	14 ..	27·08	27·05	29 ..	27·11	27·06	6 ..	27·53	27·42
August 31 ..	27·15	27·03	15 ..	27·09	26·98	30 ..	27·16	27·06	7 ..	27·49	27·43
1 ..	27·07	27·02	16 ..	27·08	26·99	Sept. 31 ..	27·11	26·98	8 ..	27·55	27·47
2 ..	27·02	26·95	17 ..	27·09	27·05	1 ..	27·02	26·98	9 ..	27·52	27·42
3 ..	27·10	27·07	18 ..	27·16	27·11	2 ..	27·06	27·06	10 ..	27·47	27·38
4 ..	27·15	27·07	19 ..	27·18	27·11	3 ..	27·13	27·15	11 ..	27·46	27·39
5 ..	27·10	26·95	20 ..	27·09	26·94	4 ..	27·10	27·08	12 ..	27·50	27·44
6 ..	27·00	26·97	21 ..	27·04	26·97	5 ..	27·03	—	13 ..	27·51	27·51
7 ..	27·08	27·04	22 ..	27·10	27·07				14 ..	27·51	27·48
									15 ..	27·53	27·46
									16 ..	27·54	27·47
									17 ..	27·56	27·46
									18 ..	27·53	27·46
									19 ..	27·56	27·51
									20 ..	27·61	27·54
									21 ..	27·61	—

Observations were taken as near to 6h. and 18h. G.M.T. each day as circumstances permitted. The readings of the dry bulb and of the extreme thermometers have been checked as far as possible against those of the sling thermometers, and corrected where necessary.

The readings are summarised in Table V. The "mean" temperature is derived from the morning and evening observations corrected to the 24-hour mean by the figures of diurnal variation derived from the records of the thermograph in 1927 (see p. 16). On the days with autographic records the correction C required was found to be approximately a linear function of the daily range R in the form

$$C (^{\circ}\text{F.}) = -2.3 + 0.22 R$$

and the observations for both 1922 and 1927 were corrected on the basis of this formula.

The mean temperature shows a well-marked double maximum in June and September. Combining the two series and reducing to a mean height of 2,000 feet by means of an assumed upward decrease of 3°F. per 1,000 feet, we obtain:—

April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
86.3	88.6	89.1	87.1	83.0	88.4	86.8	77.0	68.6

TABLE V—MEAN AND EXTREME VALUES OF TEMPERATURE

Month	Mean		Approx. height	Mean temperature			Mean daily		Highest max.	Lowest min.
	lat. N.	long. E.		6h.	18h.	mean	max.	min.		
1922	° ' /	° ' /	feet	°F.	°F.	°F.	°F.	°F.	°F.	°F.
April ..	12 10	8 30	1830	73.9	93.3	86.8	98.7	74.0	103	64
May ..	13 37	8 0	1530	76.5	95.5	90.1	103.1	74.5	109	69
June ..	14 59	9 27	1630	81.0	97.4	93.1	105.7	77.4	114	65
July ..	15 58	9 2	1660	77.3	88.8	86.7	101.1	74.3	109	64
Aug. ..	17 29	8 15	2730	76.6	82.0	81.0	90.8	72.8	99	66
Sept. ..	17 37	8 20	2870	76.1	85.5	82.9	93.2	73.1	100	67
Oct. ..	17 45	8 36	3000	68.8	85.4	81.3	94.0	64.5	100	51
Nov. ..	18 38	8 28	2400	60.8	83.1	77.5	93.7	57.9	(96)	41
Dec. ..	15 32	8 32	1730	47.3	73.2	66.2	—	45.8	—	31
1927										
June ..	14 24	8 11	1490	78.5	89.9	87.7	101.1	75.0	109	68
July ..	16 52	8 26	2120	80.4	91.0	89.2	102.3	76.1	111	69
Aug. ..	17 38	8 25	2641	74.3	81.5	80.9	95.4	71.5	102	66
Sept. ..	18 36	8 32	2920	75.8	90.1	88.5	103.0	67.5	114	55
Oct. ..	19 9	8 23	2290	76.9	91.6	88.6	102.9	73.0	(111)	(68)
Nov. ..	18 17	5 51	1410	60.9	78.9	77.2	97.4	53.9	(105)	45
Dec. ..	17 50	1 17	1310	61.7	75.2	74.0	88.9	53.4	—	(41)

The minimum in August is associated with the clouds and rain of the SW monsoon. This decrease is however almost confined to the day temperatures. The mean daily maxima in August are 5.8°F. lower than those of July and September; the night minima in August are a few degrees lower than in July, but are actually higher than those of September, owing to the rapid decrease of night temperature in the second half of the latter month, after the rains are really over. Hence the mean daily range shows a very pronounced minimum in August:—

April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
24.7	28.6	27.2	24.9	20.9	27.8	29.4	38.5	35.5

Towards the close of the year the daily range becomes very large, exceeding 40°F. on many days.¹⁰

¹⁰ A very high range of temperature was recorded on December 14/15, 1922. On the march on the 14th at 14h. 30m. the sling thermometer gave a reading of 92°F. A few miles away at Tiworshekaken the minimum on the following night was 31°F. , giving a range of 61°F.

No outstandingly high temperatures were recorded, only 9 days reaching or exceeding 110°F., distributed as follows:—June 3, July 1, September 4, October 1. The two maxima of 114° were recorded on June 24, 1922, and September 22, 1927. At the other extreme the minimum fell below freezing point on one occasion only, in December, 1922. Mr. Rodd remarks that he has perhaps encountered in his travels less than his fair share of frost at night but in 1927 rather more than his due of low day temperatures.

On several occasions during 1927 series of records were secured from the thermograph. These have been standardized by means of the eye observations and are summarised in Table VI and in Fig. 2. The latter shows several interesting features. First, there is a remarkably regular fall of temperature during the night, the decrease

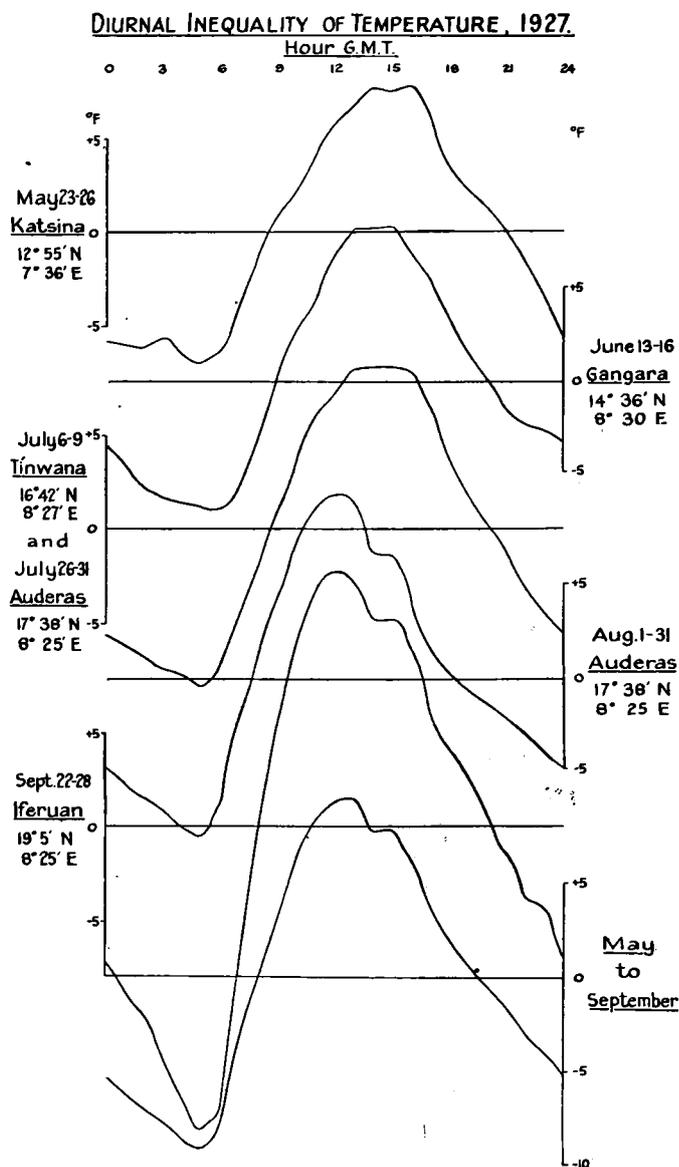


FIG. 2.

from 18h. to 5h. (the times are G.M.T. throughout) averaging almost exactly 1°F. per hour. Shortly after sunrise the steady fall is suddenly replaced by a very rapid rise, amounting to 14.3°F. in the four hours from 6h. to 10h. The night minimum is thus very pronounced, in strong contrast to the flattened minimum in moister regions. In the clear weather of the last week of September these conditions are even more pronounced, the rate of fall from 18h. to 5h. being 1.8°F. per hour, and

the rate of rise from 6h. to 10h. no less than 6.3°F . per hour. The maximum for the day occurs between 12h. and 13h., but from 14h. to 15h. there is a remarkable interruption in the fall of temperature, which almost amounts to a secondary maximum at 15h. This feature is shown more or less in all the groups of days in Table VI and is the result of a curious feature in the weather of the southern Sahara. On many days the air is very dry and the sky remains nearly clear, and temperature rises from

TABLE VI—DIURNAL INEQUALITY OF

Station	Lat. N.	Long. E.	Dates	Hours								
				0	1	2	3	4	5	6	7	
Katsina ..	13 00	7 38	May 23-26 ..	- 58	- 60	- 61	- 56	- 65	- 70	- 64	- 41	
Gangara ..	14 36	8 30	June 13-16 ..	- 35	- 45	- 58	- 64	- 66	- 68	- 70	- 59	
T'inwana ..	16 42	8 27	July 6-9 ..	}	- 56	- 62	- 69	- 75	- 77	- 85	- 73	- 47
Auderas ..	17 38	8 25	July 26-31									
Auderas ..	17 38	8 25	Aug. 1-31 ..	- 49	- 58	- 65	- 71	- 81	- 86	- 68	- 25	
Iferuan ..	19 5	8 25	Sept. 22-28 ..	- 71	- 87	- 100	- 122	- 144	- 161	- 151	- 79	
Mean ..			May to Sept. ..	- 52	- 61	- 69	- 76	- 86	- 92	- 79	- 39	

a deep minimum about sunrise to a flat maximum about 15h., falling again very steadily in the late afternoon. These are the conditions during the "quiet" days of Table VII and Fig. 3. On some days during the SW. monsoon, however, when more moisture is present, the diurnal variation of temperature follows a markedly

TABLE VII—DIURNAL VARIATION OF TEMPERATURE ON

	No. of Days	Hours									
		0	1	2	3	4	5	6	7	8	9
"Quiet" days	16	79.1	78.0	77.7	76.7	75.4	74.2	75.0	79.8	84.0	86.5
"Disturbed" days	15	75.9	75.2	74.2	73.2	72.2	72.3	74.3	77.7	81.9	85.9

different course. The morning is clear, and temperature rises rapidly until 11h. or 12h., the curve being almost identical with that for "quiet" days from 5h. to 11h. Then heavy cumulo-nimbus clouds gather, the upper NE. wind (see § 7) breaks through the south-westerly surface wind, there may be a shower of rain, and temperature falls many degrees in a few minutes. Examples of a number of such sudden drops, with the associated weather, are illustrated in Fig. 6. Temperature not infrequently falls by 20°F . or more in less than an hour. We have termed these days "disturbed." The broken curve in Fig. 3 evidently represents the combination of a number of similar curves.

The average figures of diurnal inequality for all days in Table IV were analysed by means of the harmonic series:—

$$\Delta T = a_1 \sin (t + \theta_1) + a_2 \sin (2t + \theta_2) + a_3 \sin (3t + \theta_3)$$

The constants, with the phase angles corrected to local time, are given in Table VIII.

From May to July the variation is almost a pure sine curve with its maximum at 15h. In August and September the semi-diurnal wave becomes important, reaching its maxima about 0h. and 12h. and its minima about 6h. and 18h. This component thus causes the maximum to occur earlier than 15h. and accentuates the fall of temperature during the afternoon, and evidently represents the effect of the "disturbed" days described above. This is confirmed by the components of

TEMPERATURE IN 1927 (UNIT 0.1°F.).

G.M.T.															Station	
8	9	10	11	12	13	14	15	16	17	18	19	20	21	22		23
- 16	+ 8	+ 22	+ 41	+ 59	+ 66	+ 76	+ 75	+ 77	+ 61	+ 35	+ 23	+ 12	- .2	- 17	- 37	Katsina Gangara T'inwana Auderas Auderas Iferuan
- 31	- 1	+ 28	+ 44	+ 69	+ 81	+ 81	+ 82	+ 67	+ 54	+ 34	+ 17	+ 1	- 16	- 24	- 27	
- 22	+ 8	+ 38	+ 61	+ 72	+ 86	+ 87	+ 89	+ 85	+ 67	+ 39	+ 19	+ 5	- 14	- 33	- 45	
+ 11	+ 43	+ 73	+ 92	+ 98	+ 95	+ 67	+ 65	+ 42	+ 18	+ 4	- 6	- 14	- 23	- 32	- 41	
- 4	+ 54	+ 102	+ 126	+ 137	+ 131	+ 112	+ 112	+ 96	+ 60	+ 40	+ 28	+ 7	- 15	- 38	- 43	
- 2	+ 32	+ 64	+ 84	+ 94	+ 96	+ 78	+ 78	+ 61	+ 38	+ 19	+ 6	- 5	- 18	- 31	- 41	Mean

the diurnal variation during the "disturbed" days of July, August and September, in the lowest line of Table VIII. Here the maximum of the diurnal wave comes at 13½h., the maxima of the semi-diurnal wave at 11½h. and 23½h. and its minima at 5½h. and 17½h.

" QUIET " AND " DISTURBED " DAYS, JULY TO SEPTEMBER.

G.M.T.														
10	11	12	13	14	15	16	17	18	19	20	21	22	23	
89.7	92.0	93.9	95.3	95.8	96.4	95.3	92.2	88.8	87.2	85.7	83.7	81.6	80.7	" Quiet " days
89.3	91.8	91.7	90.4	84.3	83.5	81.5	80.8	80.0	79.0	78.9	78.3	77.4	76.6	" Disturbed " days

TABLE VIII—CONSTANTS OF DIURNAL VARIATION OF TEMPERATURE

	a ₁	θ ₁	a ₂	θ ₂	a ₃	θ ₃	a ₂ /a ₁
	°F	°	°F	°	°F	°	
May 23-26	7.20	220	0.66	45	0.16	338	.09
June 13-16	7.22	219	1.82	46	0.21	344	.25
July 6-9, 26-31	8.38	224	1.28	49	0.57	352	.14
August 1-31	7.91	240	2.82	94	0.59	337	.36
Sept. 22-28	12.76	227	4.39	94	1.70	347	.35
" Disturbed " days ..	7.30	247	3.74	105	1.20	306	.51

The variation of temperature from day to day is comparatively small, but shows one interesting peculiarity, which is also connected with the alternation of "quiet" and "disturbed" days. The figures are shown in Table IX.

TABLE IX—INTERDIURNAL VARIATIONS OF TEMPERATURE

Dates	Place	6h.	18h.	Max.	Min.
1922					
April 11-28	Fanisau	2.2	3.7	0.9	2.5
August 10-20, 24-31	Auderas	2.6	5.2	2.5	2.4
Sept. 1-5, 8-30	Auderas	4.5	3.7	2.1	3.3
1927					
August 1-31	Auderas	2.7	5.9	3.3	2.8
October 1-21	Tegidda Mellen	3.2	2.1	3.7	3.2

It will be noticed that apart from the low variability of the maximum temperature in April, 1922, the figures are generally fairly uniform, with the exception of those for 18h. in August, 1922 and 1927, both of which are abnormally high. Fig. 3 shows

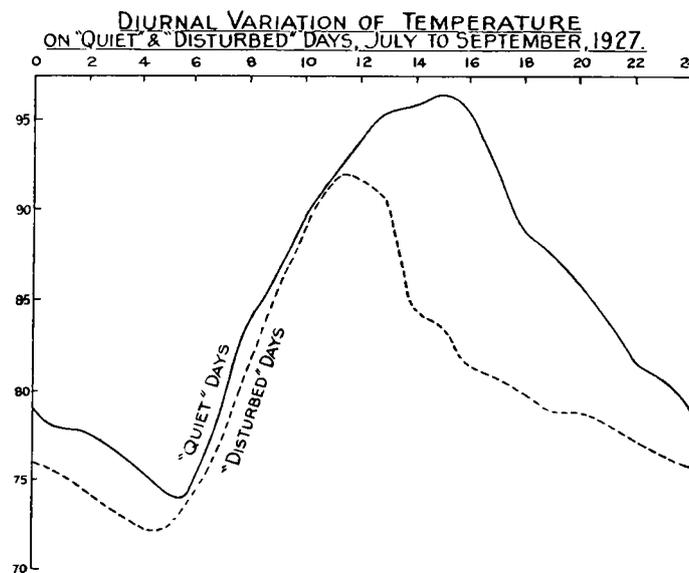


FIG. 3.

that the difference of temperature between "quiet" and "disturbed" days is greatest about 16h. and it is during August that such days alternate most frequently.

Well-water temperatures.—Table X gives details of a number of observations of the temperature of water in wells. The column headed "Depth" gives in each case the distance measured from the surface of the ground down to the water surface. The depth of water in the well was not recorded but is understood to have varied between 2 ft. and 3 ft. 6 in.

TABLE X—WELL-WATER TEMPERATURES

Date	Place	Position		Depth	Water temp.	Air temp. at surface	Mean air temp. for month
		Lat. N.	Long. E.				
1922 May 6 ..	Katsina ..	13 00	7 38	66	84	96	90.1
1927 June 11 ..	Kurdidifi ..	14 31	8 28	102	81	94	87.7
" " 24 ..	Tinawgarakan ..	15 18	8 16	82½	85.5	97	87.7
" Sept. 16 ..	Tintaralle ..	18 27	8 56	10½	79.5	91	88.5
" Nov. 28 ..	Tanekert ..	17 49	3 11	31½	84	60	77.2

For the 1927 figures, the ventilation was assumed sufficient and the vapour pressure and relative humidity were worked out from the Meteorological Office Tables referred to above.

While it is hoped that the procedure adopted may have removed some uncertainties in the 1922 readings, the latter must be regarded as definitely inferior in accuracy to those obtained in 1927.

At times the formulæ became invalid, thus at 18h. on 17th June, 1922, the readings of the dry and wet bulb were 101.6° and 67.0° F. The usual procedure in this case leads to a negative vapour pressure, and the reading was neglected for computation of the mean value of the vapour pressure, while a nominal value of 2 per cent was entered, in this and similar cases, for computing the mean relative humidity.

Another difficulty occurred in April, 1922, when on one occasion the difference between dry bulb and "sling" reading was such that the computed vapour pressure was higher than the saturation vapour pressure corresponding with the "sling" reading. In this case the relative humidity was taken as 100 per cent. After the exposure of the dry and wet bulb was improved (see § 2) the differences between dry bulb and "sling" readings were much smaller.

Table IX shows the average readings of the relative humidity and vapour pressure at the morning and evening observation hours in 1922 and 1927. The figures indicate that June was much drier in 1922 than in 1927 and this point seems to be supported by an observation in 1927 that "the wind experienced crossing the Azawagh steppe desert between Damergu and Air was prevalently SW. to W., though in 1922 it was NE."

While both sets of figures show a double maximum and minimum, experienced as the expedition moved northward, it seems more probable that the course of events at a fixed station near the northern limit of the expedition would include only a single maximum, and from remarks in the weather diaries it appears that Mr. Rodd's expedition in 1922 was probably keeping slightly in advance of the northward trend of the belt of "the rains," which "follows the sun" northward through Nigeria, but in 1927 the rains were ahead of the expedition. In 1927 it was considered that the rainy season had opened while the expedition was in Nigeria.

In 1922 hourly readings of the wet and dry bulb thermometers were taken on three days. The values of relative humidity and vapour pressure computed from these are shown in Table XII, and serve to some extent to indicate the nature of the diurnal variation of these elements. The relative humidity on two of these days is shown in Fig. 4, from which the variations are seen to depend almost entirely on those of the temperature. The curves suggest that the relative humidity reaches a

TABLE XII—HOURLY READINGS, 1922 EXPEDITION

Hour		6½h.	8h.	9h.	10h.	11h.	12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.
KATSINA. May 7—	Dry °F. ..	81.0	81.0	85.4	89.0	91.8	93.0	94.0	96.6	96.0	95.4	94.0	93.5	—	—	—	—
	Wet °F. ..	61.6	—	62.4	62.5	69.0	71.0	71.8	73.4	73.6	71.1	73.2	73.8	—	—	—	—
	R.H. % ..	15	—	8	2	16	20	20	20	20	16	25	27	—	—	—	—
	V.P. mb. ..	5.3	—	3.5	1.0	8.3	10.6	11.1	11.9	11.6	9.0	13.4	14.7	—	—	—	—
AUDERAS. Sept. 9—	Dry °F. ..	75.8	81.0	83.8	85.4	88.0	—	88.5	89.0	88.8	78.5	74.0	71.2	—	—	—	—
	Wet °F. ..	70.6	72.0	74.0	74.2	74.8	—	74.9	75.0	74.5	72.0	68.0	68.0	—	—	—	—
	R.H. % ..	72	57	55	51	45	—	44	43	41	67	67	81	—	—	—	—
	V.P. mb. ..	22.0	20.5	21.8	21.1	20.2	—	20.1	19.9	19.2	22.3	19.2	21.2	—	—	—	—
AUDERAS. Sept. 24—	Dry °F. ..	78.0	83.5	88.1	92.3	94.0	95.5	—	94.4	95.0	91.9	92.0	90.0	87.9	86.9	86.8	86.6
	Wet °F. ..	65.2	69.0	70.0	71.2	71.5	72.0	—	73.0	73.5	70.0	71.2	72.0	71.0	67.9	67.4	67.8
	R.H. % ..	38	36	28	22	19	18	—	23	23	19	23	29	31	23	22	23
	V.P. mb. ..	12.3	14.1	12.5	11.4	10.6	10.4	—	12.8	13.2	9.8	11.6	14.2	14.1	10.1	9.4	10.1

For the 1927 figures, the ventilation was assumed sufficient and the vapour pressure and relative humidity were worked out from the Meteorological Office Tables referred to above.

While it is hoped that the procedure adopted may have removed some uncertainties in the 1922 readings, the latter must be regarded as definitely inferior in accuracy to those obtained in 1927.

At times the formulæ became invalid, thus at 18h. on 17th June, 1922, the readings of the dry and wet bulb were 101.6° and 67.0° F. The usual procedure in this case leads to a negative vapour pressure, and the reading was neglected for computation of the mean value of the vapour pressure, while a nominal value of 2 per cent was entered, in this and similar cases, for computing the mean relative humidity.

Another difficulty occurred in April, 1922, when on one occasion the difference between dry bulb and "sling" reading was such that the computed vapour pressure was higher than the saturation vapour pressure corresponding with the "sling" reading. In this case the relative humidity was taken as 100 per cent. After the exposure of the dry and wet bulb was improved (see § 2) the differences between dry bulb and "sling" readings were much smaller.

Table IX shows the average readings of the relative humidity and vapour pressure at the morning and evening observation hours in 1922 and 1927. The figures indicate that June was much drier in 1922 than in 1927 and this point seems to be supported by an observation in 1927 that "the wind experienced crossing the Azawagh steppe desert between Damergu and Air was prevalently SW. to W., though in 1922 it was NE."

While both sets of figures show a double maximum and minimum, experienced as the expedition moved northward, it seems more probable that the course of events at a fixed station near the northern limit of the expedition would include only a single maximum, and from remarks in the weather diaries it appears that Mr. Rodd's expedition in 1922 was probably keeping slightly in advance of the northward trend of the belt of "the rains," which "follows the sun" northward through Nigeria, but in 1927 the rains were ahead of the expedition. In 1927 it was considered that the rainy season had opened while the expedition was in Nigeria.

In 1922 hourly readings of the wet and dry bulb thermometers were taken on three days. The values of relative humidity and vapour pressure computed from these are shown in Table XII, and serve to some extent to indicate the nature of the diurnal variation of these elements. The relative humidity on two of these days is shown in Fig. 4, from which the variations are seen to depend almost entirely on those of the temperature. The curves suggest that the relative humidity reaches a

TABLE XII—HOURLY READINGS, 1922 EXPEDITION

	Hour	6½h.	8h.	9h.	10h.	11h.	12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.
KATSINA. May 7—	Dry °F. ..	81.0	81.0	85.4	89.0	91.8	93.0	94.0	96.6	96.0	95.4	94.0	93.5	—	—	—	—
	Wet °F. ..	61.6	—	62.4	62.5	69.0	71.0	71.8	73.4	73.6	71.1	73.2	73.8	—	—	—	—
	R.H. % ..	15	—	8	2	16	20	20	20	20	16	25	27	—	—	—	—
	V.P. mb. ..	5.3	—	3.5	1.0	8.3	10.6	11.1	11.9	11.6	9.0	13.4	14.7	—	—	—	—
AUDERAS. Sept. 9—	Dry °F. ..	75.8	81.0	83.8	85.4	88.0	—	88.5	89.0	88.8	78.5	74.0	71.2	—	—	—	—
	Wet °F. ..	70.6	72.0	74.0	74.2	74.8	—	74.9	75.0	74.5	72.0	68.0	68.0	—	—	—	—
	R.H. % ..	72	57	55	51	45	—	44	43	41	67	67	81	—	—	—	—
	V.P. mb. ..	22.0	20.5	21.8	21.1	20.2	—	20.1	19.9	19.2	22.3	19.2	21.2	—	—	—	—
AUDERAS. Sept. 24—	Dry °F. ..	78.0	83.5	88.1	92.3	94.0	95.5	—	94.4	95.0	91.9	92.0	90.0	87.9	86.0	86.8	86.6
	Wet °F. ..	65.2	69.0	70.0	71.2	71.5	72.0	—	73.0	73.5	70.0	71.2	72.0	71.0	67.9	67.4	67.8
	R.H. % ..	38	36	28	22	19	18	—	23	23	19	23	29	31	23	22	23
	V.P. mb. ..	12.3	14.1	12.5	11.4	10.6	10.4	—	12.8	13.2	9.8	11.6	14.2	14.1	10.1	9.4	10.1

low value as early as about 10h. and remains low until about 15h. The variations of vapour pressure are small, but there are indications that this element reaches its minimum about 10h.

The difference between September 9 and 24 is conspicuous. In this connexion remarks from the weather diary give the probable explanation. As regards September 9, it is noted that after noon, temperature fell rapidly with the approaching rain, while the day's rain was more than usually heavy. This was probably a "disturbed" day of the type mentioned in § 4. On September 13 it was noted that the rains appeared to be over.

The driest period encountered in 1927 was during October, in which month out of 24 readings of relative humidity at 18h. none exceeded 25 per cent, 20 were below 20 per cent and 5 below 10 per cent, the minimum reading being 7 per cent on October 1 and the mean for the month 15 per cent.

A figure of 7 per cent was also reached on September 12 and 21 at 18h., these exceptionally low readings being all associated with wet-bulb depressions of 30° or more. Taking the maximum temperatures for these days, and assuming the vapour pressures to have remained constant, approximate values can be derived for the minimum relative humidity for the days, in each case of 5 per cent. Such a figure while very low is not unprecedented, values of 2 per cent having been obtained at several stations. The vapour pressure is generally high in the months of the SW. monsoon, but falls to very low values in the autumn. As showing the variability of this climate, it may be mentioned that the

conditions encountered in the mornings of the first few days in June, when temperature was between 75° and 80° and relative humidity about 80 per cent, corresponded closely with average conditions for the same time at Lagos, a coastal station some 500 miles nearer the equator.

The interdiurnal variability of relative humidity for periods when camp was fixed for several days is shown in Table XIII.

TABLE XIII—INTERDIURNAL VARIABILITY OF RELATIVE HUMIDITY

Place and date	6h.	18h.
AUDERAS.		
1922.	%	%
August 10-20 }	10	18
24-31 }		
September 1-5 }	17	17
8-30 }		
1927.		
August 1-31	9	19
TEGIDDA MELLEEN.		
1927.		
October 1-21	6	5

SERIES OF READINGS ON TWO DAYS IN SEPT. 1922.

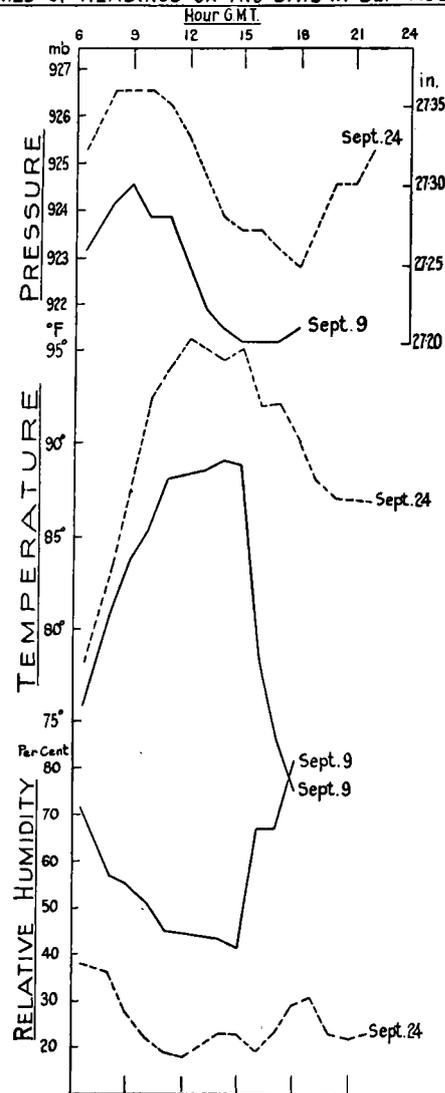


FIG. 4.

The high figure for 6h. in September 1922 may be associated with disturbed conditions at the close of the rainy season. On several occasions a strong E. wind blew all night, while on other mornings the wind was calm or westerly.

As further evidence of the transport of appreciable quantities of water vapour into the Sahara by "monsoon" winds, the numbers of occasions on which dew was observed in the various months of 1927 are given in Table XIV together with the corresponding mean dry-bulb and dew-point figures.

TABLE XIV—TEMPERATURES OF AIR AND DEW POINT ON MORNINGS ON WHICH DEW WAS RECORDED.

Month	No. of occasions of dew	Morning observations on these days					
		Mean dry-bulb temperature	Mean dew-point temperature	Difference			
				Average	Slight dew	Dew	Heavy dew
		°F.	°F.				
June ..	12	77*	67*	10	11	11	4
July ..	6	78	62	16	19	23	12
Aug. ..	22	74	64	10	12	12	7
Sept. ..	5	73	44	29	37	21	9
Oct. ..	2	74	35	39	39	—	—
Nov. ..	2	58	29	29	35	24	—

* 11 occasions only.

The observations for September, October and November point to the extraordinary difference of temperature between the ground and the air which must occur on the rare occasions when dew is formed. In the months of the SW. monsoon the humidity of the air is much greater and a moderate degree of cooling is sufficient, so that dew is frequent, especially in August.

§ 6—WINDS

Mr. Rodd's observations of wind direction at fixed hours, mainly 6h. and 18h., were supplemented by very full notes of the changes during the day, and often during the night as well. Hence the best way of summarising them appeared to be to estimate the total duration of winds from different directions each day, and to convert

TABLE XV—PERCENTAGE FREQUENCY OF WINDS FROM DIFFERENT DIRECTIONS.

	Average Lat.	Position Long.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm
1922.	° /	° /									
April ..	12 10	8 30	0	5	7	21	1	41	3	3	19
May ..	13 37	8 0	4	3	17	9	5	23	6	14	19
June ..	14 59	9 27	0	3	30	25	0	33	1	0	8
July ..	15 58	9 2	2	5	3	1	0	21	66	0	2
August ..	17 29	8 15	1	7	8	11	2	32	7	12	20
September ..	17 37	8 20	0	4	49	4	0	3	18	4	18
October ..	17 45	8 36	0	1	39	51	1	0	0	0	8
November ..	18 38	8 28	0	0	25	19	1	17	11	4	23
December ..	15 32	8 32	0	55	14	10	0	0	9	1	11
1927.											
May 22-31 ..	13 00	7 40	3	8	5	6	9	16	9	1	43
June ..	14 24	8 11	0	3	1	2	6	34	17	8	29
July ..	16 52	8 26	2	2	3	0	1	21	35	10	26
August ..	17 38	8 25	9	9	18	8	0	7	12	13	24
September ..	18 36	8 32	4	25	26	10	0	2	0	0	31
October ..	19 9	8 23	13	51	11	2	2	2	0	1	18
November ..	18 17	5 51	7	29	13	0	0	2	0	1	48
December 1-15 ..	17 50	1 17	10	30	20	0	0	7	4	5	24

the monthly totals into percentages of the total number of hours observed. The results for 1922 and 1927 are given in Table XV. It will be seen that from April to August, 1922, and from May to July, 1927, the prevailing winds were southerly or south-westerly, while from September to December easterly winds prevailed. In August, 1927, westerly and easterly winds were of approximately equal frequency. The resultant directions were as follows:—

	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1922 ..	SSW.	SSW.	SE.	W.	SW.	E.	ESE.	SSE.	ENE.
1927 ..	—	SSW.	WSW.	W.	NNE.	ENE.	NE.	NE.	NE.

In the northern part of the northern province of Nigeria the observations show that the north-easterly winds continue to prevail until some time in March, and are steadiest in December and January, while the SW. winds are steadiest in June.

Between Taberghit and Tagedufat (about 16° N., 8-9° E.) to the south of Air, the small mobile crescentic sand dunes, the horns of which point down wind, indicate a prevailing direction from E. or NE.

During the SW. monsoon there was a tendency for the winds in the early morning to be more westerly and those in the late afternoon to be more south-westerly, while the occasional bursts of north-easterly wind (see below) were limited to the middle of the day. During the NE. monsoon there was a slight tendency for the winds to be more northerly in the morning and more easterly in the afternoon. Both tendencies represent a veer of the wind and probably result from the increasing turbulence during the day, but the changes were not very definite. The wind force showed a distinct maximum at mid-day; where definite estimates were made the distribution was as follows:—

TABLE XVI—PERCENTAGE FREQUENCIES OF WINDS OF DIFFERENT FORCE

Force	Calm	1-3	4-7	8 or more
Morning ..	47	51	2	0
Mid-day ..	7	80	10	3
Evening ..	35	60	5	0

Upper Winds.—For 1927 a number of observations of the direction of cloud motion are available. These are shown in Table XVII, divided into two periods May 24 to August 13 and August 14 to December 16, which roughly correspond with the prevalence of surface winds from SW. and NE. respectively. The clouds were divided into two classes, lower cloud, chiefly cumulus and nimbus, and middle or

TABLE XVII—SUMMARY OF OBSERVATIONS OF CLOUD MOTION

	Direction from (per cent.)									No. of obs.
	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm	
MAY 24-AUG. 13—										
Lower cloud	3	49	26	13	3	2	2	2	0	39
Corresponding surface wind	2	10	8	8	13	24	15	5	15	39
Upper cloud	0	40	33	17	3	0	2	2	3	30
Corresponding surface wind	0	3	0	0	3	33	13	10	38	30
AUG. 14-DEC. 16—										
Lower cloud	2	21	52	10	0	7	3	5	0	41
Corresponding surface wind	11	33	18	6	2	5	1	4	20	41
Upper cloud	0	10	74	0	3	7	3	3	0	30
Corresponding surface wind	8	17	15	0	0	0	0	3	57	30

upper cloud, chiefly cirro-stratus, cirro-cumulus and cirrus. During the first period the prevailing direction of motion of lower clouds was from NE., in direct opposition to the surface winds. The upper clouds moved from a slightly more easterly direction than the lower clouds. Comparison with the surface-wind directions at the time of observation brings out two interesting points; first that during the occurrence of low cloud north-easterly winds at the surface are fairly frequent even during the SW monsoon. This is especially true of nimbus clouds, which seem to be carried on a powerful burst of the north-easterly upper current, often powerful enough to sweep away the surface layer of air moving in the opposite direction and to extend down to ground level. On these occasions the wind frequently attains gale force. The second point is the greater frequency of surface calms with high cloud than with low; this results partly from the converse phenomenon that when low cloud is absent the wind is generally light, and partly from the large number of observations of upper cloud which were taken at 6h.

During the second period, from August 14 to December 16, the upper winds are more in accord with the surface-wind directions, though with a progressive deflection towards the E. The resultant direction of the surface winds during this period, measured from N. towards E., is 52° , that of the lower cloud 82° and of the upper cloud 89° .

On October 19th, 1927, two levels of "high" cloud were observed, cirro-cumulus moving from E. and, above that, cirrus moving from W.

§7—AMOUNT AND TYPE OF CLOUD

The cloud observations made in 1927 have been analysed with the results shown in Tables XVIII-XXI. The observations have been grouped in periods of two

TABLE XVIII—FREQUENCY OF DISTRIBUTION OF DIFFERENT TYPES OF CLOUD, AS PERCENTAGES OF NUMBER OF CLOUD OBSERVATIONS

Type	Morning	Mid-day	Afternoon	Evening	Morning	Mid-day	Afternoon	Evening
	May and June				July and August			
Ci.	30	12	3	7	34	14	9	6
Ci.-St.	—	11	6	14	—	—	—	—
Ci.-Cu.	27	12	12	17	34	7	9	23
A.-St.	—	—	—	—	2	—	—	2
A.-Cu.	—	—	—	—	—	—	3	2
St.-Cu.	—	4	—	—	2	—	—	2
Nb.	5	4	30	31	2	39	44	41
Cu.	3	42	40	14	12	36	26	19
Cu.-Nb.	5	—	6	—	—	—	3	2
St.	30	15	3	17	14	4	6	23
No. of observations } }	37	26	33	29	44	28	34	52
	September and October				November and December			
Ci.	19	10	18	3	28	15	27	13
Ci.-St.	11	3	5	3	19	23	21	13
Ci.-Cu.	30	3	3	15	22	8	5	9
A.-St.	—	—	—	—	—	—	—	—
A.-Cu.	2	3	—	3	—	—	—	—
St.-Cu.	9	—	3	12	—	—	—	—
Nb.	2	16	21	26	—	8	5	5
Cu.	6	42	42	12	—	—	5	5
Cu.-Nb.	2	3	—	—	—	—	—	5
St.	19	20	8	26	31	46	37	50
No. of observations } }	47	31	38	34	32	13	19	22

months owing to the comparatively small number of observations, and the method of dividing up the day was chosen so as best to utilize the numerous observations made between the usual morning and evening hours. Consideration of the original figures shows that no important feature of the cloud conditions is obscured by this method of grouping except perhaps the variations from month to month in frequency of Nb., Cu., and St. clouds; the figures for these separately are therefore given in Table XIX.

TABLE XIX—FREQUENCY OF OCCURRENCE OF NB., CU. AND ST. CLOUDS IN PERCENTAGES OF NUMBERS OF CLOUD OBSERVATIONS

	Morning	Mid-day	Afternoon	Evening	Morning	Mid-day	Afternoon	Evening
	May				June			
Nb. ..	22	—	22	57	—	5	33	18
Cu. ..	—	17	33	14	4	50	42	14
St. ...	33	50	11	29	29	5	—	14
	July				August			
Nb. ..	—	27	38	19	4	47	54	44
Cu. ..	6	18	24	12	15	47	31	19
St. ...	13	9	10	19	15	—	—	19
	September				October			
Nb. ..	—	21	32	38	4	8	6	8
Cu. ..	9	58	45	14	4	17	37	8
St. ...	22	5	—	10	17	42	19	54
	November				December			
Nb. ..	—	—	—	—	—	17	14	10
Cu. ..	—	—	8	—	—	—	—	10
St. ...	22	29	25	50	43	67	57	50

It will be seen that in all months there is a considerable diurnal variation of cloud, specially marked in the monsoon season as is to be expected from what has already been said about the sequence of weather on a "disturbed" day. Convection cloud is prominent from May to October, but in November and December there is an increase in St. cloud. The reason for the increase in frequency of St. is not clear—it may be an expression of change in longitude as well as of change of type, or of season, the first three weeks or so of November showing little cloud whereas the last week of November and the part of December in which the observations continued showed a considerable increase of cloud. On November 28 it was noted that "since the 22nd the sky has been covered nearly every day up to 10/10 with this Ci. and Ci. St. which however was transparent with blue sky everywhere more or less visible," while regarding the first part of December: "Throughout the last fortnight the weather has been cloudy nearly every day with skies of 10/10 covered all day . . . Drops of rain fell several times, but although the sky was often very threatening no prolonged rain fell . . . The clouds seemed for the most part to be coming from N. or W. of N."

These observations might indicate the change toward the January type of pressure distribution when the surface "high" is centred about lat. 30° N. and the pressure gradient at 3,000 metres is for westerly winds. On the other hand, the weather of November and December, 1927, was described as unusual by the natives both of Air and Ifoghas. But the weather was unusual not in type but in persistency. In November, 1922, a short period of cloudy weather was observed, the cloud coming from the N., over southwesterly surface winds. The rain-cloud of November-December, 1927, also came from N. or W. of N. This is the direction whence the

Air winter rains (see p. 29, second paragraph of note under October 14, 1927) used to come according to the natives, who recognize the difference in type between these and the usual summer rains.

TABLE XX—PERCENTAGE FREQUENCIES OF OCCURRENCE OF VARIOUS CLOUD AMOUNTS (scale 0—10)

Observed cloud amount	Morning	Mid-day	Afternoon	Evening	Mean of day*	Morning	Mid-day	Afternoon	Evening	Mean of day*
	May and June					July and August				
0	34	26	24	30	5	42	25	8	20	12
1	15	11	9	14	8	17	15	—	18	7
2	8	7	—	3	26	12	5	8	4	7
3	2	4	9	3	10	5	—	15	2	15
4	2	15	5	—	10	2	—	15	9	15
5	2	11	14	6	8	2	5	—	2	17
6	2	—	—	2	10	2	10	8	4	3
7	5	—	5	3	13	3	—	—	2	22
8	—	4	5	14	2	9	5	15	7	—
9	10	11	5	3	5	3	10	8	18	—
10	20	11	24	22	3	3	25	23	14	2
No. of observations	41	27	21	36	39	59	20	13	45	41
	September and October]					November and December				
0	44	40	24	48	27	37	41	25	47	31
1	10	12	20	5	17	7	—	6	12	11
2	10	—	—	4	6	10	—	—	3	8
3	2	4	4	7	2	2	6	6	5	—
4	10	—	—	—	6	—	—	—	—	5
5	2	4	4	11	17	—	—	—	3	8
6	4	—	—	2	9	—	6	—	—	3
7	2	—	—	5	8	2	6	13	3	8
8	4	4	12	5	4	7	—	—	—	—
9	4	8	4	2	4	14	12	19	7	13
10	8	28	32	11	—	21	29	31	20	13
No. of observations	50	25	25	44	48	43	17	16	40	38

* Estimated from consideration of all available information in the weather diaries. In some cases, as when only a morning observation was made, it was not possible to estimate the mean for the day.

The values of mean cloudiness are given in Table XXI. The figures for the mean of the month are in satisfactory agreement with those deduced from the maps of mean cloudiness given by Sir Napier Shaw (Manual of Meteorology, Vol. II).

TABLE XXI—VARIATION OF MEAN CLOUDINESS (Tenths of sky covered)

	Morning	Mid-day	Afternoon	Evening	Mean
May-June ..	3.9	3.9	4.8	4.5	4.1
July-August ..	2.4	4.9	5.9	4.7	4.0
Sept.-Oct. ..	2.7	4.3	5.0	3.1	3.2
Nov.-Dec. ..	4.4	4.9	5.9	3.3	4.1

§ 8—RAIN AND OTHER PHENOMENA

The area traversed by Mr. Rodd lies wholly within the summer rainfall belt, the northern limit of which corresponds fairly accurately with the northern geographical boundary of Air at the pools of Tarazit (about 20° N.). In Air the rains appear according to the natives to be divided into three parts:

(1) those which fall in July, rarely before the 14th, and last a few days; three or four good falls may be expected. Then follows a brief rainless period before

(2) the August rains ; these are the useful rains. Then there should be a further brief interval of a few days fine weather, of which the period at the end of August and beginning of September, 1927, was described as being quite characteristic. This is followed by

(3) the fitful September rains, which may include heavy rains but are more usually irregular showers of varying intensity, tailing off into the October weather of which 1922 was more characteristic than 1927. Typical of these rains were the showers on September 9, 10 and 15, 1927. On the 9th showers fell from 17h. 30m. to 18h. 45m. but on the 10th and 15th the rain, although relatively copious above the hot surface stratum of air, scarcely reached the ground.

The extreme dates for the first rains of sufficient volume to fill stream beds of a certain size with flood water, are June 3, recorded by von Bary east of Bagezan in 1877, and September 1, recorded by Barth in northern Air in 1850, but both these dates seem to be exceptional.

Most of the rainfall is of the "tornado" type, falling in short heavy showers nearly always between noon and sunset. It is very local, heavy showers often being visible at a distance while no rain, or at most a few drops, fell near the camp. Mr. Rodd records, however ("People of the Veil," p. 123) that :

"During my stay at Auderas there were a few days when the sky was overcast for the whole of the twenty-four hours, with little rainfall ; the damp heavy feeling in the air reminded one of England, as the atmosphere was cold and misty. On one particular day it rained lightly and fitfully for fourteen hours on end with occasional heavy showers. Such phenomena, however, are rare. Precipitation follows a north-easterly wind and usually lasts three or four hours ; as soon as the westerly wind, prevalent at this season, has sprung up, the nimbus disperses rapidly, leaving only enough clouds in the evening to produce the most magnificent sunsets that I have ever seen."

The incidence of the rains varies from place to place, being generally earlier in the south than the north, though there are many irregularities. Hence Table XXII, which gives the number of days with rain (including days on which rain was seen falling in the vicinity) recorded by Mr. Rodd, shows a more extended rainy period than would have been recorded in Air alone.

TABLE XXII—FREQUENCIES OF RAIN

Month 1922	No. of days with rain	No. of days of observa- tions	Month 1927	No. of days with rain	No. of days of observa- tions
April ..	4	30	May ..	6	10
May ..	7	31	June ..	12	30
June ..	6	30	July ..	13	31
July ..	14	31	August ..	24	31
August ..	18	31	September ..	12	30
September ..	12	30	October ..	6	31
October ..	2	31	November ..	2	30
November ..	0	30	December ..	5	15
December ..	0	30			

On the occasions in 1927 on which the rain-gauge was in use, a few falls at the rate of 2 inches or more per hour were measured, for example on June 18 1.04 inches fell in 30 minutes. Several falls during August were at rates of between one and two inches per hour. The full list is shown in Table XXIII. These intense falls produce violent floods in valleys where normally the water-courses are dried up.¹⁴

¹⁴ All the valleys in the area visited by the expedition are normally dry even during the rains. The only exceptions are two or three ravines high up in the Bagezan and Tamgak Mountains where there are said to be perennial rivulets or springs with a few hundred yards of flowing water. When rain does fall, the valleys, even the largest, flow very strongly and violently, starting and ceasing very suddenly. In one or two areas on the outskirts of Air these flood waters make "sumps" where the ground remains soft and is often impossible by camel for weeks at a time. F.R.

The "tornadoes" are generally accompanied by considerable perturbations of the diurnal temperature change (see pp. 18 and 21) but the corresponding disturbance of the pressure changes is less marked.

TABLE XXIII—RAINFALL RATES 1927.

May	27;	.53 in. nearly all in 10 min. ; equivalent to 3.0 in./hr. (approx.).
June	18;	1.04 " " fell in 30 " " " " 2.1 "
August	3;	.15 " " 20 " " " " 0.5 "
"	13;	.44 " " 25 " " " " 1.1 "
"	14;	.22 " " 20 " " " " 0.7 "
"	22;	.19 " " 60 " " " " 0.2 "
"	23;	.48 " " 20 " " " " 1.4 "
"	28;	.2 " " 6 " " " " 2.0 "
September	2;	.35 " " 12 " " " " 1.7 "
	45;	" " 50 " " " " 0.5 "

There is a tendency for the tornado to be accompanied by a slight rise of pressure which prevents the usual afternoon minimum of pressure being attained. Fig. 5 shows the diurnal inequalities of pressure on "quiet" and "disturbed" days in August and Fig. 6 gives tracings of selected thermograms, with the corresponding barograms, and notes on the weather.

On August 10 the disturbance of the temperature was accompanied by comparatively little barometric change, while on September 24 the reverse occurred, the barograph trace showing a fairly well marked disturbance, while the thermograph was hardly affected.

On August 23 it was noted that "The temperature drop did not precede the afternoon storm as it usually does by about $\frac{1}{4}$ to $\frac{1}{2}$ hour."

The tornado seems to be due in some way to interaction between the upper north-easterly current and the lower, damp, monsoon winds,¹⁵ but the mechanism of the process is not clearly understood. Under the average conditions about the times to which the tracings of the autographic curves refer, a statical change of about 2 mb. (.06 in.) in pressure would be produced if the lowest half kilometre of air were replaced by air 25° colder.

The parts of the curves reproduced are from 12h. to 19h. except (f), which runs from 11h. to 18h. The tracings are intended to show the relative values of the temperature and pressure changes, instrumental corrections for absolute values not being indicated. The corrections necessary to the thermograms are, however, small. The base line for the barogram varies from about 28 inches in July to 27 in August and 27.5 in September, the lines across the traced parts being at intervals of 0.1 inch (3.4 mb.).

The following are extracts from the weather notes for the days in question :

July 7—" 1.30 p.m. Cu. and Nb. gathering to E. and NE. A part passed N., but centre of storm apparently broke on camp; wind E. with squalls force 9-10, wind generally force 8 and 7. Storm began about 1.55 p.m.; by 2.30 rain finished, 0.63 inches had fallen. Drizzle continued till 4.15 p.m., further .05 inch fell. Wind between 2.30 and 4 backed through N. to W., whence sudden hot squalls force 5 and 6. Sky clearing south, east and north-east. Squalls ceased just before 5. The later ones were less hot and violent. Wind dropped to calm at 5.15 p.m. Colourless sunset. Cloud 5, Ci. and Ci-Cu. (NE.)."

August 10—" 12.50 p.m. slight shower from NE. 2.15 p.m. sharp shower preceded by gusts NE. force 3."

August 13—" 1.20-1.45 p.m. very heavy rain. Storm came from east. Wind E., SE., S. and then SW. Storm passed W., whence N., travelling E."

August 14—" 1 p.m. first drops. 1.30 storm from E., .22 inch rain in 20 minutes. Passed W. then curled round to N. and returned, a few drops falling.

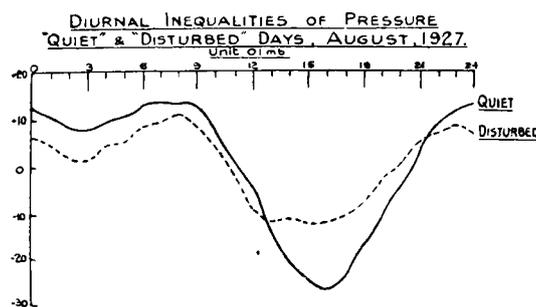
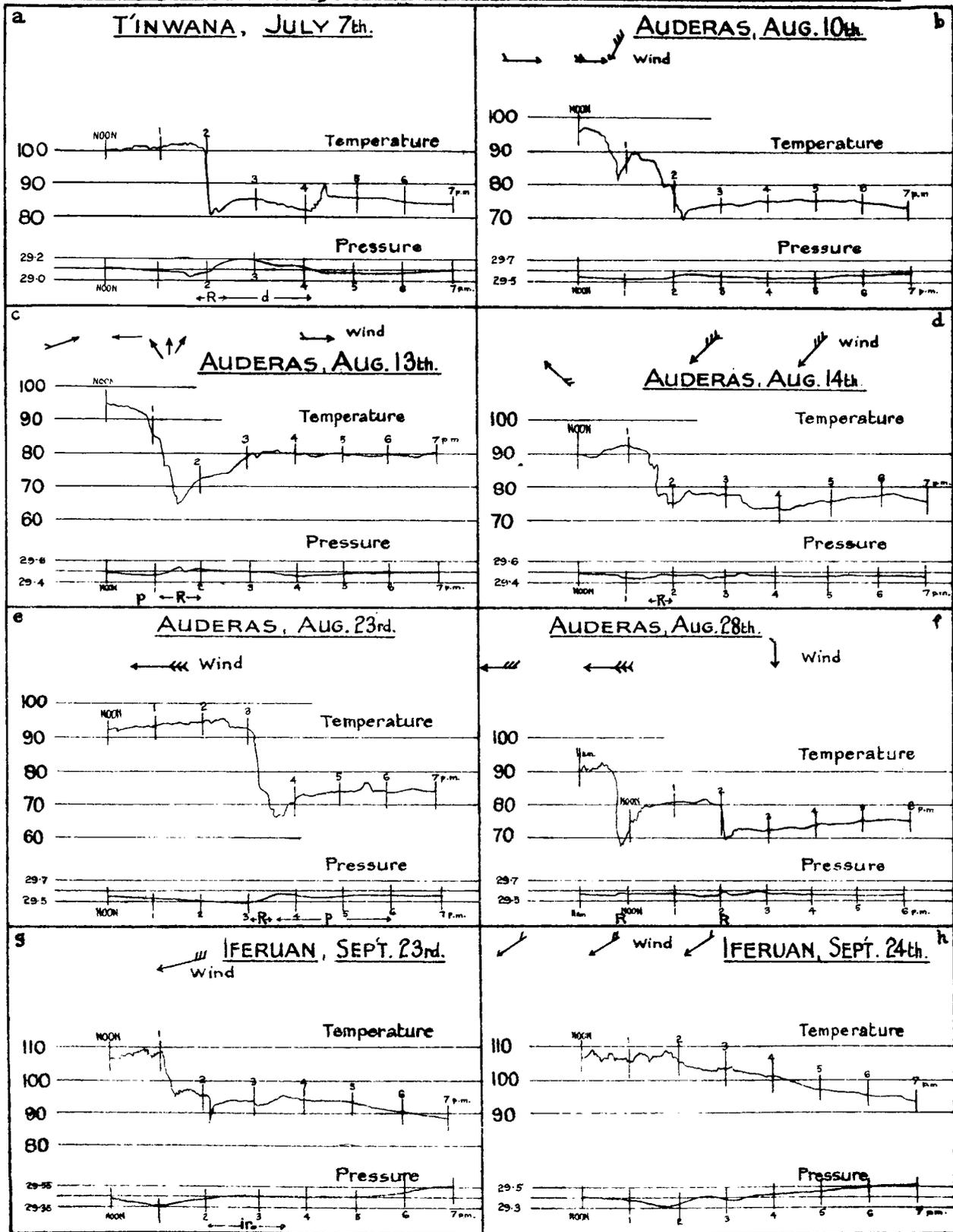


FIG. 5.

WIND, TEMPERATURE & PRESSURE ON SELECTED DAYS IN 1927.



#2830

FIG. 6.

Marcy & Sons, Inc.

- August 23—" Storm gathering 1.15 p.m. NE. to SE. horizon. Rain preceded by strong puffs and squalls up to force 6 from E. Heavy rain 3.10 to 3.30 then light showers till 6 p.m."
- August 28—" 11.45 a.m. wind E. 3, cloud Nb. 6 from ENE. 0.2 inch fell in 6 minutes.
2 p.m. wind E. 6, cloud Nb. 10 from ENE., rain driven by gale. .35 inch in 12 minutes."
- September 23—" 1 p.m. Very heavy packs of Cu. appeared to E., by 2 p.m. whole sky was covered with moderately high Cu and lower Nb. A good deal of rain fell in mountains, but over camp only three small showers of short duration between 2 p.m. and 3.30 p.m."
- September 24—" 3 p.m. Some Nb. and Cu. visible to E. and SE.
4 p.m. considerable Nb. came over from E., sky at most times 9/10 covered, till sun-down, when Nb. low on W. and S. horizon."

These examples give a description of typical rainy-season weather in this part of the Sahara. Rain during the night is not unknown, though rare. On one occasion in 1922 rain fell practically without interruption for 14 hours.

Some remarks regarding the rainy season in general may be quoted :—

- 1922 : September 8—"—the weather continues in the rainy season. The normal amount is 10 days rain this moon and 20 days last moon. With the end of this moon the rainy season closes. This year the rain at Auderas has been more than usual; on the other hand practically none is said to have fallen in Ighazar, though further west at Zurika and Agellal it is normal."
- "With the storms the wind moves round a good deal. It is generally blowing SW. when they come up. Then it comes from NE. moving to N., NW., W. and SW. again."
- 1922 : September 22—" E. wind still continues and with it a clear blue sky. The E. wind appears normal after the rains. To the south the rains are followed by a drying wind which dries the crops. The rains are certainly over."
- 1922 : November 16—" It is said that it used to rain in Air after the tropical or summer rains in the late autumn and in late October and November in the olden days, but it is 20 years or more since that happened. This second rain appears to be coincident with the rain in the Fezzan and Ghat areas in the late autumn and early winter corresponding with the European rainy season."
- 1922 : November 21—" It is noticeable that during the cloudy days that we have been having, the otherwise regular E. and SE. winds gave place to a SW. wind and that the clouds came from the N., much the same symptoms observed during the rainy season. This is probably the weather which used to come when the rains fell in Air in the late autumn."
- 1927 : October 14—" On the 2nd considerable quantities of cloud appeared and have been manifested almost daily since then, for the most part appearing some time after sunrise from the NE. or E. Occasionally higher clouds have been seen coming from the NW., but these have been difficult to remark as they have appeared on days when there was much cloud about at lower levels coming from the NE."
- " These late, October, rains have been conspicuously absent in Air during the last 10 years by all accounts. When they occur they are supposed to betoken good autumn and winter rains in the Sahara subjected to the Mediterranean régime and good rains in Air during the next summer season following."
- 1927 : November 1—" The conclusion is that practically no rain has fallen this year between Tamgak (lat. 19) and Tarazit (lat. 20) though an almost exceptional amount in the latter area." (In the Tarazit area and rather east of the Tarazit massif is the Grebun massif which is probably the highest group in Air.)
- 1927 : December—" Throughout the last fortnight the weather has been cloudy nearly every day with skies often covered all day. . . . Drops of rain fell several times but although the sky was often very threatening no prolonged rain fell. The clouds seemed for the most part to be coming from N. or W. of N."

Sandstorms may occur alone, or as the precursors of rainstorms. Examples may be quoted from the weather diary :

- 1927 : June 15—" Dust storm from SE., wind force 4, but no rain : began 4 p.m., over by 4.40 p.m. Height of dust about 70 feet. Wind speed measured just before dust and wind arrived 1,490 ft. per min." (17 m.p.h.)
- 1927 : June 23—" 1/10 Ci. from NE. at 10 a.m. At noon cumulus appeared from NE. and E., by 3 p.m. heavy low nimbus approaching from E. with SW. and W. 1 wind in puffs. At 3.45 p.m. a cloud of sand probably 100 ft. high appeared, preceded by a calm. It suddenly commenced blowing E. 5 with much sand and went on for 20 minutes. Then steady rain. Most of the storm passed south of us ; storm went away west. Rain fell for about 45 minutes steadily and not hard, laying sandstorm which went on ahead of the rain."

Dust-devils were observed on many occasions. One which passed near the camp on July 26, 1927, caused a sudden drop in pressure of nearly 2 mb. Another on October 18, 1927, struck the camp at 15h. giving rise to a wind of force 8 momentarily, and then moved north at an estimated speed of 10 to 15 m.p.h.

Other phenomena.—The frequencies of thunder, lightning and zodiacal light are shown in Table XXIV. Very distant thunder and lightning were observed frequently but not recorded.

TABLE XXIV—FREQUENCY OF OCCURRENCE OF VARIOUS PHENOMENA

1922	Thunder	Lightning	Zodiacal light	No. of days	1927	Thunder	Lightning	Zodiacal light	No. of days
April ..	2	5	2	30	May ..	1	3	—	10
May ..	2	2	—	31	June ..	1	2	—	30
June ..	—	1	—	30	July ..	—	1	—	23
July ..	1	1	—	31	Aug. ..	5	5	—	31
Aug. ..	1	1	—	31	Sept. ..	2	—	6	30
Sept. ..	1	1	—	30	Oct. ..	—	—	—	31
Oct. ..	—	—	—	31	Nov. ..	—	—	4	30
Nov. ..	—	—	—	30	Dec. ..	—	1	—	15
Dec. ..	—	—	—	30					

§ 9—VISIBILITY

In 1927 several observations of visibility were made, the entries being usually descriptive, as "fair," "very hazy," and less commonly expressed as distances. These observations, being somewhat irregularly made, have not been summarised in the usual way, but have been classified broadly under two headings as shown in Table XXV.

TABLE XXV—SUMMARY OF VISIBILITY OBSERVATIONS 1927

Visibility	May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.	
	6h	18h	6h	18h	6h	18h	6h	18h	6h	18h	6h	18h	6h	18h	6h	18h
"Very fair" and above ..	3	3	12	9	5	—	13	5	18	16	4	3	27	18	1	—
"Fair" and below ..	—	—	2	4	3	5	8	3	8	3	5	4	—	1	1	1
Total of observations ..	3	3	14	13	8	5	21	8	26	19	9	7	27	19	2	1

These observations indicate that visibility was best in May, June and November and worst from July to October. Low visibilities seem to be due to dust haze which often reduces the visibility to 1 mile or less. Sandstorms on occasion were noted as reducing visibility to a quarter of a mile and to 50 yards. There seems to be a considerable diurnal variation, haze increasing during the day on several occasions while morning and evening were clear, but on one or two days in July visibility was better about mid-day, and in August there was a tendency for haze in the mornings. In the latter part of October it was noted that "Visibility as usual with NE. winds has often been poor during the day but improved always to good and very good at sundown and at night when it has often been exceptionally good." In September, 1922, it was noted that "NW. wind brings haze all over the country, often very thick."

"*Heat flicker*" was noted on many occasions in May and June, but seldom afterwards.

Mirage was noted both in 1922 and 1927 wherever the ground was suitable after leaving latitude 15° N. It was of such frequent occurrence that only in exceptional cases is it alluded to in the diaries. It was seen in May (1922), June, July, September, October (1922 and 1927) and November (1927), both in the deserts south and west of Air and in the mountainous plateau itself, though not in narrow valleys.

Mirage on November 12, 13, 14 and 15 was so remarkably bad that at noon visibility fell at times to 200 yards in certain directions and was never more than two miles between 9h. and 15h. It extended all round the horizon. The desert here was exceedingly flat, the surface being small gravel lying on hard sand.

On November 14 the mirage was very bad even in the early morning. Some low hills called Ajir were seen for two hours flickering, but sufficiently formed to allow the natives to recognize their profile above the bank of mirage when the caravan was south of Tan Adar—a distance of at least 40 miles. Just before noon they disappeared and were not seen again until three days later from another direction 20 miles away. Normally when there is only a slight mirage they are not visible from the point south of Tan Adar on account both of distance and of intervening sand ridges. They are so low that in clear weather they only become visible at a distance of some 20 miles from a direction where no ridges intervene. The natives regarded this phenomenon as most interesting. The mirage lay in its correct bearing; the mirage bank was perhaps 2° high and the hills some $1\frac{1}{2}$ — 2° above it.

APPENDIX

METEOROLOGICAL DIARIES KEPT BY F. R. RODD, 1922 AND 1927.

Day.	Station.	Lat. N.	Long. E.	Height ft. *	Temperature.				Relative Hu- midity.		Remarks.
					† 6h.	† 18h.	Max.	Min.	6h.	18h.	
April, 1922.					°F.	°F.	°F.	°F.	%	%	
1	Kano	12 4	8 33	2000	82.1	91.1	94.0	81.6	74	46	Sun through haze all day.
2	.. .. .	..	..	..	80.5	..	..	80.0	63	..	Fresh SW. wind all day.
3	Fanisau	12 5	8 33	1700	80.1	92.5	95.0	80.0	60	42	Hot day. Fresh SW. wind.
4	.. .. .	..	..	..	76.0	95.5	96.0	76.0	75	49	Much cloud at night.
5	.. .. .	..	..	..	74.0	95.0	96.0	74.0	93	25	Few drops rain 21h.
6	.. .. .	..	..	..	75.5	90.2	98.0	75.5	84	40	Squalls at 15h. 55m. and 20h.
7	.. .. .	..	..	..	74.0	95.1	95.4	74.0	95	38	Nb. over all sky 18h.
8	.. .. .	..	..	..	76.0	94.0	97.5	76.0	82	27	Cloud disappeared in afternoon.
9	.. .. .	..	..	..	67.2	91.0	99.0	67.2	56	30	Haze afternoon and night.
10	.. .. .	..	..	..	64.0	95.1	100.3	64.0	..	..	Sky covered morning, clear afternoon.
11	Fanisau .. .. .	..	..	..	70.0	89.0	96.2	70.0	..	..	Sky covered morning, clear afternoon.
12	.. .. .	..	..	..	75.4	90.8	99.0	75.2	..	..	Afternoon clear.
13	.. .. .	..	..	..	69.0	89.0	98.0	68.0	..	..	Haze morning, clear sky all day.
14	.. .. .	..	..	..	67.1	91.0	98.3	67.1	..	..	Clear all day.
15	.. .. .	..	..	..	65.3	97.7	99.0	65.3	..	..	Clear sky all day.
16	.. .. .	..	..	..	67.0	94.6	99.2	67.0	94	19	Gusts of wind from E. and SE. p.m.
17	.. .. .	..	..	..	64.0	88.6	100.1	64.0	100	25	Very hot in sun.
18	.. .. .	..	..	..	74.8	91.8	100.1	72.2	55	31	Clear hot day.
19	.. .. .	..	..	..	78.3	..	99.1	75.9	73	..	Sharp squall 16h. 30m. Rain 17h. and 18h. 55m.
20	.. .. .	..	..	..	76.7	92.6	98.1	75.7	76	55	Sun hidden nearly all day.
21	.. .. .	..	..	..	75.9	92.0	99.9	75.9	88	46	Much small Cu. cloud about.
22	.. .. .	..	..	..	76.2	92.6	99.1	76.2	85	49	Hot and rather windless all day.
23	.. .. .	..	..	..	77.7	97.5	100.9	77.7	76	40	Flecks of Cu. all day. Much St. sundown.
24	.. .. .	..	..	..	..	96.0	101.4	78.4	..	51	Strong breeze with dust a.m. Very hot p.m.
25	.. .. .	..	..	..	82.5	97.0	101.6	82.0	69	36	Nb. at 18h., but no rain came.
26	.. .. .	..	..	..	80.3	100.6	103.5	80.3	71	..	Very sticky and hot last night.
27	.. .. .	..	..	..	..	98.5	103.4	..	..	..	17h. wind changed SE. and white haze came up.
28	Dowano .. .. .	..	..	1780	72.5	..	..	72.2	..	..	Visibility very bad all day.
28	Bechi .. .. .	..	..	1850	..	96.2	..	..	..	..	..
29	Dan Zabua .. .. .	..	..	1840	..	94.0	..	..	..	..	Sun hardly shining through haze and much dust.
30	.. .. .	..	..	..	..	..	..	80.0	..	..	Less haze but visibility still bad.
30	Kusada .. .. .	..	..	1820	..	93.5	..	..	..	..	..
May, 1922.											
1	Bindawa .. .. .	..	..	1800	..	98.0	..	..	..	..	Sun shone strongly all day.
2	Bindawa .. .. .	..	..	..	74.0	..	..	72.4	..	..	Clear day, hardly any haze.
2	Rimi .. .. .	..	..	1700	..	98.0	..	..	..	..	..
3	Rimi .. .. .	..	..	..	81.1	..	..	74.0	..	..	Westerly breeze from 9h.
3	Katsina	13 00	7 38	1660	..	98.0	..	..	..	..	..
4	.. .. .	..	..	..	79.0	99.8	..	..	..	..	Clear day, some Cu. patches.
5	.. .. .	..	..	..	..	96.4	..	..	..	..	White sky, though clear all day.
6	.. .. .	..	..	..	76.9	95.0	99.5	..	..	15	White sky with much glare.
7	.. .. .	..	..	..	81.0	93.4	98.0	80.9	15	27	Fresh E. breeze, white sky.
8	.. .. .	..	..	..	..	..	..	68.6	..	..	Fresh E. wind after 9h.
8	Dan Kaba	13 13	7 45	1470	..	99.8	104.2	..	..	32	..
9	.. .. .	..	..	..	79.0	91.2	98.4	78.8	65	47	White sky all day.
10	.. .. .	..	..	..	75.2	97.5	102.5	76.0	70	32	Clear hot day.
11	.. .. .	..	..	..	76.0	84.2	100.0	78.2	77	67	Showers 15h. 5m. to 19h. 30m.
12	.. .. .	..	..	..	75.0	93.0	100.5	76.0	90	52	Very little breeze all day.
13	.. .. .	..	..	..	75.3	97.9	103.2	75.6	76	18	Clear morning, very hazy afternoon.
14	.. .. .	..	..	..	75.4	97.0	102.4	74.2	56	14	Visibility very poor all day.
15	.. .. .	..	..	..	68.5	100.0	108.6	68.5	40	6	Puffs of hot wind from N. all afternoon.
16	.. .. .	..	..	..	62.6	96.0	103.0	63.8	32	26	Much dust in the air.
17	.. .. .	..	..	..	78.5	97.0	104.0	68.6	62	30	Very hot to-day.
18	.. .. .	..	..	..	82.0	..	..	72.0	..	..	Looked very like rain; rain fell to W.
18	Nr. Gangara .. .. .	..	..	..	..	85.4	..	..	..	..	..
19	.. .. .	..	..	..	74.4	..	..	73.0	..	..	Sky became 9/10 covered at 18h. 30m.
19	Nr. Yadawa .. .. .	..	..	..	..	92.4	100.4	..	..	..	..
20	.. .. .	..	..	..	80.0	..	..	..	..	..	Violent sandstorm from SW. preceded rain.
20	Tessawa	13 46	7 59	1330	..	80.8	99.8	..	..	67	..
21	.. .. .	..	..	..	77.5	97.2	102.2	76.0	83	18	Violent tornado from E. 19h.
22	.. .. .	..	..	..	78.8	..	106.0	76.0	74	..	Heavy Nb. 17h. but no rain.
23	.. .. .	..	..	..	81.0	96.2	103.6	79.3	59	37	Little wind day, cool SE. wind evening.
24	.. .. .	..	..	..	79.5	97.6	103.8	79.0	68	43	NW. breeze p.m. with flecks of Cu.
25	.. .. .	..	..	..	80.5	92.0	97.2	80.5	60	44	Sky covered a.m., cleared p.m.
26	.. .. .	..	..	..	76.4	..	..	74.8	..	..	Cloudy, clearing by noon, then rain 16h. 20m.
26	Matashi .. .. .	..	..	..	..	98.0	..	..	..	..	..
27	.. .. .	..	..	..	..	..	..	78.2	..	..	..
27	Urufan	14 05	8 06	1380	..	98.0	105.6	..	..	16	NW. breeze from 10h.
28	.. .. .	..	..	..	77.0	98.0	107.5	75.4	61	28	All clouds apparently from E. and N.E.
29	.. .. .	..	..	..	..	..	..	75.6	..	..	Wind SE. at noon, thin white cloud over sky.
29	Garari .. .. .	..	..	1450	..	102.0	107.0	..	..	..	..
30	.. .. .	..	..	..	73.2	98.1	108.0	71.0	..	..	Small Cu. from SE. all day.
31	.. .. .	..	..	..	..	97.9	109.2	69.0	..	..	Some squalls from E. 15h.-16h.

* Heights printed in italics have been computed in the Meteorological Office from the pressure readings by aneroid in conjunction with any other available data.
† 1922: Sling thermometer readings are given when available; the readings in italics are from the sheltered thermometer (see p. 7).

Day.	Station.	Lat. N.	Long. E.	Height ft. *	Temperature.				Relative Hu- midity.		Remarks.
					† 6h.	† 18h.	Max.	Min.	6h.	18h.	
June, 1922.											
1	Garari .. ..	..	..	1450	..	..	..	77.6	..	..	Violent SE. wind with sand, 15h. 30m. to 16h. 10m. Wind then returned to SW.
1	Agaji .. ..	..	..	1500	..	99.7	105.2	..	..	..
2	Gangara	14 36	8 30	2057	..	91.7	100.4	..	..	35	Spots of rain 16h. 46m. and 17h. 15m.
3	.. ..	..	..	..	81.2	98.1	102.8	78.0	74	22	No gusts of wind to-day.
4	.. ..	..	..	..	93.2	95.0	101.0	80.6	17	22	Wind SW. till early p.m., then SE.-E.
5	.. ..	..	..	..	84.0	99.0	104.0	81.0	46	22	Small Cu. noon and p.m. St-Cu. sundown.
6	.. ..	..	..	..	82.2	96.0	106.0	81.0	38	2	SW. wind and clear sky all day.
7	.. ..	..	..	..	85.2	100.2	106.4	83.0	30	10	SW. wind, clear sky a.m. Much Cu. from E. p.m.
8	Gogowa .. ..	..	..	1740	..	101.0	104.0	..	..	..	Clear day till 16h., sandstorm 18h.
9	In Bush .. ..	..	..	..	76.0	..	..	74.5	..	..	SE. wind and white sky from 8h. onwards.
9	Tanut	14 58	8 52	1720	..	97.6	..	..	..	9	
10	.. ..	..	..	..	77.9	97.0	103.0	76.2	31	3	SE. wind persisted, but haze less bad.
11	.. ..	..	..	..	79.8	94.9	98.0	78.6	52	2	One or two squalls from E. to NE.
12	.. ..	..	..	..	81.9	92.3	101.8	80.2	22	21	Rain fell a few miles off.
13	.. ..	..	..	..	77.0	..	..	74.8	56	..	Clear a.m., much Cu. and Cu-Nb. about 16h.
15	Garasu	14 27	9 33	1670	..	101.7	105.0	..	..	18	SE. wind and small Cu. from noon onwards.
17	Djom	14 35	9 56	1650	82.0	101.6	108.0	76.0	37	2	Clear day, SE. wind.
18	.. ..	..	..	..	75.0	..	..	73.0	36	..	E. wind all day, very hazy.
19	Bultum	14 37	10 12	1680	82.0	99.8	110.9	81.2	10	5	White haze and E. wind till 15h. when Nb. from NE.
20	In Bush .. ..	..	..	..	..	100.4	..	..	..	..	Strong gusts during day from E. and SE.
21	Tasr	14 55	10 45	1365	..	98.2	108.0	..	..	31	E. wind and white streaky sky all day.
22	Tasker	15 07	10 43	1434	..	96.0	106.0	..	..	4	Wind E. to NE. from noon.
23	In Desert .. ..	..	..	..	..	97.0	105.9	..	..	4	A little Ci. and Ci-St., otherwise clear all day.
24	.. ..	..	..	..	..	99.3	113.9	..	..	..	White haze: visibility never more than 1½ miles.
25	.. ..	..	..	..	..	..	113.0	..	..	..	No wind till 13h. then E. very hot.
26	Termet	16 04	11 09	2198	..	..	107.0	..	..	..	Strong E. wind all day, violent gusts 12h.-17h.
27	.. ..	..	..	..	..	94.0	..	..	..	..	Much haze afternoon.
28	.. ..	..	..	..	91.4	91.8	106.1	81.4	..	7	E. wind with haze noon till sunset.
29	.. ..	..	..	..	74.6	99.0	106.9	65.5	13	8	E. wind and some haze all day.
30	.. ..	..	..	..	78.8	..	107.7	72.7	22	..	SW. wind with Cu. till 15h. then ENE. with clear sky.
July, 1922.											
1	Termet	16 04	11 09	2198	76.6	98.6	107.0	69.9	27	16	W. wind with clear sky from noon. No clouds.
2	.. ..	..	..	..	77.6	..	..	67.5	41	..	No clouds, except small St. over sunset.
3	On March .. ..	..	..	..	75.2	..	..	..	..	..	SW. wind all day: no clouds.
4	Halt in Dunes .. ..	..	..	..	72.8	..	..	..	..	..	SW. breeze till 22h., when Nb. and Cu-Nb. from NE.
5	Tasker	15 07	10 43	1434	81.7	97.1	108.8	73.0	..	..	Wind varying SW. to NE., with much cloud from NE.
6	Bullum Baba .. ..	..	..	1388	78.2	..	..	..	..	..	W. wind all day with much cloud.
7	In Bush .. ..	..	..	..	79.5	..	..	78.2	..	..	Cloud all day from E.
7	On March .. ..	..	..	..	..	96.0	..	..	..	..
9	In Bush .. ..	..	..	..	..	..	..	64.0	..	..
9	Ighelaf	15 11	9 29	1420	..	86.4	..	..	..	..	West wind, but Cu. from E. all day.
10	.. ..	..	..	..	..	..	..	72.0	..	..
10	Guliski	15 02	9 12	1670	72.6	89.2	..	..	..	..	17h. heavy rainstorm from E. passed south.
11	Gamram	15 04	8 53	1590	..	85.0	..	..	..	..	Ci-St. till 13h., then Cu. and finally Nb.
12	.. ..	..	..	..	75.5	..	..	..	..	..	W. wind all day: Ci. and Ci-St. a.m., Cu. p.m.
12	Hannekar	15 09	8 44	1475	..	90.8	..	..	..	..
13	.. ..	..	..	..	80.8	83.4	94.0	78.0	..	..	Rain fell a.m. and p.m. Storms in progress all round.
14	.. ..	..	..	..	74.0	89.8	96.1	67.5	..	..	Many storms to S., coming from E.
18	Valley of Eghalgawen .. ..	..	..	..	..	91.8	..	..	..	..	Violent W. wind 8h. to 15h.
19	T'invana	16 42	8 27	2218	..	..	104.0	..	..	..	River rose (rain from hills) 18h. 30m.
20	.. ..	..	..	..	..	..	98.0	83.0	..	..	Heavy rain clouds in evening.
21	.. ..	..	..	..	..	..	102.0	85.0	..	..	Heavy rainclouds to S. in evening.
22	.. ..	..	..	..	..	..	103.0	81.5	..	..	Less close but hot.
23	.. ..	..	..	..	..	..	106.0	80.0	..	..	W. wind all day.
24	.. ..	..	..	..	..	..	106.0	75.0	..	..	Rain 17h. 30m. to 18h. 15m.
25	Tebehic	16 48	8 21	1645	..	92.0	94.5	76.0	..	..	Rain 17h. 10m. to 19h.
26	.. ..	..	..	..	83.0	90.0	108.0	73.0	..	..
27	.. ..	..	..	..	..	76.0	102.0	80.0	..	..
28	.. ..	..	..	..	..	..	91.0	72.0	..	..
29	.. ..	..	..	..	..	82.0	96.0	73.0	..	..
30	Tintaborak .. ..	..	..	1560	..	..	..	76.0	..	..	Hurricane from NE. with sand, then rain 17h. 15m. [to-18h.
31	.. ..	..	..	..	..	..	..	..	..	..
31	Agades	16 59	7 59	2047	..	93.8	..	..	..	30	

* Heights printed in italics have been computed in the Meteorological Office from the pressure readings by aneroid in conjunction with any other available data.

† 1922: Sling thermometer readings are given when available; the readings in italics are from the sheltered thermometer (see p. 7).

Day.	Station.	Lat. N.	Long. E.	Height * ft.	Temperature.				Relative Hu- midity.		Remarks.
					† 6h.	† 18h.	Max.	Min.	6h.	18h.	
					°F.	°F.	°F.	°F.	%	%	
August, 1922.											
1	Agades	16 59	7 59	2047	82.0	95.0	99.0	81.5	71	28	S. wind a.m. : hardly any wind p.m.
2	79.0	87.0	97.0	77.0	65	39	SW. wind till evening, then NE. with raincloud.
3	82.0	87.9	96.3	80.0	66	53	Sand and squalls 16h. 30m., then rain.
4	78.0	80.0	89.0	74.0	84	78	Nb. over all W. sky at sunset. No rain.
5	77.5	79.7	95.6	77.0	87	70	Heavy rain 15h. overcast till sunset.
6	75.0	..	..	72.5	92	..	..
6	Nr. Azzal	..	..	..	..	87.9	..	..	..	..	21h. Cu-Nb. from E. : few drops rain 22h.
7	74.0	..	..	74.0	..	..	9/10 Cu-Nb. from NE. all morning.
7	Solom Solom	17 18	8 4	1930	..	73.0	..	..	..	..	Cleared 12h., then Nb. and 12h. by 16h. 30m.
8	69.0	..	..	68.0	..	..	Hot and damp ; no wind till 9h. then NW.
8	Assa	..	..	2320	..	77.0	..	..	..	..	Cu. from NE. at 12h., then Nb. Rain 13h. 35m.
9	67.5	..	..	67.0	..	..	Cu. all morning, Nb. 12h.
9	Okuluf.	..	..	..	..	81.7	..	..	..	..	Overcast with Nb. at sunset.
10	67.5	..	..	67.0	..	..	Damp all morning. Heavy cloud overhead 13h.
10	Auderas	17 38	8 25	2641	..	75.0	..	..	..	77	[Only light rain.
11	73.0	85.0	92.0	71.5	82	50	Cloudy all day. Nb. and Cu. from E.
12	76.1	82.5	88.0	74.3	81	60	22h. 30m. violent gale from NE., heavy rain.
13	76.5	75.0	87.5	72.0	78	84	River in high flood.
14	71.0	74.0	87.5	69.0	90	90	Little wind all day.
15	73.5	80.0	..	72.0	88	69	Rain under uniform grey sky 12h. to 14h.
16	74.0	76.0	82.0	71.5	83	83	Rain 13h. 50 m. and 16h.
17	74.0	83.8	87.5	69.4	84	65	No rain to-day. 22h. violent gale from SE.
18	81.0	82.0	88.0	72.0	48	51	SE. gale blowing all day.
19	77.0	79.3	88.0	72.8	68	66	Heavy shower 18h. 35m. to 18h. 50 m.
20	74.0	74.0	85.3	72.0	84	68	Very heavy rain 12h. 50m. to 14h. 15m.
21	66.0	..	..	SW. breeze all day.
21	Towar	17 36	8 33	3327	..	84.0	..	..	..	..	Nb. from NE. 12h. Drops of rain 13h. 50m.
22	72.0	84.0	..	69.0	..	..	15h. haze appeared, lasting till sunset.
23	75.8	..	..	..	..	..	..
23	Auderas	17 38	8 25	2641	..	86.2	..	..	..	..	..
24	77.5	88.5	92.5	73.0	52	23	Rather close.
25	75.0	90.0	95.0	73.0	64	16	Very close and heavy.
26	78.3	83.0	94.0	73.0	45	38	E. wind and haze a.m. Haze continued p.m.
27	79.0	76.8	91.5	77.4	61	70	Rain about 15h.
28	75.6	87.4	92.0	73.0	68	38	Some Nb. about 16h. but dissolved.
29	77.0	89.0	95.5	75.0	63	23	Some haze a.m.
30	77.5	81.5	96.0	77.0	59	54	Thunder-bolt fell to N.
31	75.4	76.6	91.0	72.5	72	65	Rather close : very damp night.
Sept., 1922.											
1	Auderas	17 38	8 25	2641	75.0	76.6	91.0	73.0	66	65	Rain from E., hurricane wind 13h. 35m.
2	74.0	83.0	86.5	71.8	74	54	Little wind all day.
3	78.0	76.5	91.5	76.0	62	72	Light rain, covered sky all evening.
4	71.8	80.5	86.8	71.0	84	56	W. wind till 15h., then Nb. from NE., and E. wind.
5	71.6	..	..	71.0	90	..	SE. fresh wind all day.
5	Towar	17 36	8 33	3327	..	84.6	..	..	..	..	..
6	72.6	80.0	..	71.5	..	..	Drops rain early and late p.m.
7	74.5	..	..	67.5	..	..	NE. wind changed to NW. gale 8h.
7	Auderas	17 38	8 25	2641	..	76.2	..	..	..	..	14h. 20m. very strong E. wind, then calm till sunset.
8	73.0	87.0	91.0	71.0	79	37	Very heavy rain to N. all afternoon.
9	75.8	71.2	91.0	74.5	72	81	Heavy rain, river in high flood.
10	73.0	..	..	69.5	91	..	W. wind all day.
11	87.0	93.0	..	..	34	No clouds till noon, then Nb.
12	73.4	76.0	89.0	71.5	88	58	No clouds till noon, then showers 14h. 30m. to 16h. 20 m.
13	76.0	86.2	91.0	72.0	46	51	No wind all day, haze over all country.
14	86.4	89.0	91.9	72.0	79	22	Clear day, with strong E. wind.
15	75.0	87.0	93.0	73.9	64	65	Hot and close : some haze all round.
16	75.2	82.6	95.8	74.3	60	52	Very close and heavy from 17h.
17	70.4	84.0	94.7	68.8	61	59	Some Nb. early p.m., showers 15h. 40m.
18	72.4	89.0	96.0	70.5	61	18	After 18h. steady E. wind. Very dry.
19	75.0	89.8	94.5	70.5	56	13	Haze all day : fresh E. wind from 9h.
20	84.0	85.0	94.0	77.9	15	23	Fresh E. wind all day (strong early a.m.).
21	82.7	87.8	93.0	79.3	14	16	E. wind to 16h., then haze to 19h. 30m., when E. wind again.
22	75.7	88.0	96.2	74.0	37	18	Hardly any haze.
23	82.0	89.0	95.0	81.0	27	21	E. wind with intervals of W. wind all day.
24	78.0	90.0	96.0	77.0	38	29	Very heavy and hot when no wind.
25	72.8	90.0	97.2	71.0	48	57	Some cloud a.m., disappeared by noon.
26	77.7	88.6	96.1	74.8	28	16	..
27	73.5	88.5	94.4	68.0	37	20	Gentle E. wind, stronger in afternoon.
28	74.0	89.0	94.5	73.0	43	22	Last two days sun remarkably clear.
29	83.0	90.0	95.5	78.0	..	..	E. wind all day.
30	76.2	92.0	100.0	75.7	34	23	Fine clear day.

* Heights printed in italics have been computed in the Meteorological Office from the pressure readings by aneroid in conjunction with any other available data.
 † 1922 : Sling thermometer readings are given when available ; the readings in italics are from the sheltered thermometer (see p 7).

Day.	Station.	Lat. N.	Long. E.	Height *	Temperature.				Relative Hu- midity.		Remarks.
					† 6h.	† 18h.	Max.	Min.	6h.	18h.	
				ft.	°F.	°F.	°F.	°F.	%	%	
Oct., 1922.											
1	Auderas	17 38	8 25	2641	82.0	91.0	100.0	80.0	25	18	SE. to E. breeze all day.
2	.. ..	..	..	..	75.6	90.4	100.0	72.0	32	20	—
3	.. ..	..	..	..	82.4	90.0	95.0	72.5	20	..	—
4	.. ..	..	..	..	62.3	..	..	60.0	..	..	SE. wind from 9h.
4	El Baghdadi .. ..	..	..	..	..	82.0	..	..	..	..	—
5	.. ..	..	..	..	74.0	..	..	65.0	..	..	SE. wind from 7h. Very pleasant travelling.
5	Assada Vall.	17 49	8 18	2805	..	88.6	..	..	..	..	—
6	.. ..	..	..	..	73.0	..	..	66.5	..	..	Fresh E. wind all day. No clouds. till 17h. when
6	Elazzas Vall. .. ..	..	..	..	..	86.2	..	..	..	..	[small patches in W.]
7	.. ..	..	..	..	82.0	..	95.4	68.5	3	9	Fresh E. wind all day.
8	.. ..	..	..	..	77.5	..	..	71.8	..	..	Fresh E. wind all day.
8	Abarakan	18 03	8 42	2950	..	86.2	..	..	..	..	No clouds at all.
9	.. ..	..	..	..	77.0	..	..	68.5	..	..	Clear day ; no clouds.
9	Timia	18 07	?	3470	..	86.0	..	..	..	..	—
10	.. ..	..	..	..	73.0	86.0	90.5	69.6	22	7	Clear day ; no clouds.
11	.. ..	..	..	..	74.5	..	91.4	70.0	9	..	No clouds.
12	.. ..	..	..	..	68.5	..	..	67.5	..	..	A little Cu. noon to sunset, increasing to N. from
12	Abarakan	18 03	8 42	2950	..	88.2	..	..	..	..	[16h.]
13	.. ..	..	..	..	75.0	..	..	60.5	..	..	Wind E. to ESE. all day.
13	Teginjir	17 59	..	3520	..	83.2	..	..	..	..	A little thin St. or Ci-St. at times.
14	.. ..	..	..	..	57.0	..	..	51.5	..	..	Very little wind all day.
14	Tamanet .. ..	..	..	3220	..	85.0	..	..	..	..	—
15	.. ..	..	..	..	52.5	..	..	51.5	..	..	Rather hot travelling.
15	Tellia	17 47	8 53	3130	..	86.2	..	..	..	..	A little small Cu. p.m. Clear sunset.
16	.. ..	..	..	..	69.0	85.0	99.0	58.0	24	4	Hot. No clouds all day.
17	.. ..	..	..	..	59.0	..	..	59.0	..	..	S.E. wind all day from 9h. A little Ci. after 15h.
17	Teloas Valley .. ..	..	..	3130	..	86.2	..	..	..	..	[till sunset.]
18	.. ..	..	..	..	59.0	..	..	59.0	..	..	Light SE. wind from 9h. ; no cloud.
18	Tabello	17 35	8 55	2690	..	86.0	..	..	..	..	—
19	.. ..	..	..	..	61.0	87.0	95.0	59.3	45	5	SE. wind ; no cloud.
20	.. ..	..	..	..	61.7	61.2	92.0	60.0	26	27	Light SE. wind from roh. ; no cloud.
21	.. ..	..	..	..	61.2	85.0	93.0	57.2	29	..	SE. wind from 9h.
22	.. ..	..	..	..	61.0	84.0	92.0	58.3	32	8	Very little wind all day.
23	.. ..	..	..	..	65.0	83.0	90.0	59.6	22	9	Slight haze.
24	.. ..	..	..	..	59.0	..	91.2	58.5	51	..	Clear sky ; hot day.
25	.. ..	..	..	..	59.2	..	..	58.8	25	..	Clear a.m. ; some St. to S. and W. p.m.
25	Nr. Adkakit .. ..	..	..	..	..	85.6	..	..	..	..	—
26	Nr. Adkakit .. ..	..	..	..	61.8	..	..	61.7	..	..	Light E. to SE. winds.
26	Towar	17 36	8 33	3327	..	85.4	..	..	..	..	—
27	.. ..	..	..	..	73.7	87.2	..	70.4	..	..	SE. wind all day ; some Ci. a.m.
28	.. ..	..	..	..	80.3	..	..	79.4	..	..	SE. wind ; Ci. afternoon and sunset ; some haze all
28	Auderas	17 38	8 25	2641	..	87.4	..	..	..	..	[day.]
29	.. ..	..	..	..	77.0	87.0	..	72.2	12	2	Dust-devil (clockwise) over camp 15h.
30	.. ..	..	..	..	71.2	87.0	92.0	69.0	34	10	Clear day ; no haze ; no clouds.
31	.. ..	..	..	..	66.2	81.2	93.0	65.0	33	23	No clouds ; cool and clear.
Nov., 1922.											
1	Auderas	17 38	8 25	2641	76.7	85.5	93.0	69.0	16	17	SE. breeze steady all day.
2	.. ..	..	..	..	75.0	87.0	95.7	69.0	22	10	SE. wind, no clouds.
3	.. ..	..	..	..	58.0	..	..	58.0	..	..	No clouds ; visibility good.
3	Ighaghar .. ..	..	..	3075	..	86.2	..	..	..	..	—
4	.. ..	..	..	..	56.4	..	..	..	..	..	Much Ci. all day.
4	Assada	17 49	8 18	2805	..	82.5	..	..	..	..	—
5	.. ..	..	..	..	43.0	..	..	43.0	..	..	No wind till 13h. then fresh SW. till sundown ; no
5	Aggata	18 09	8 33	2525	..	86.2	..	..	..	..	[clouds.]
6	.. ..	..	..	..	45.0	..	..	43.4	..	..	Light SW. breeze 12h. till sunset ; fresh E. wind
6	Assode	18 27	8 29	2395	..	78.0	..	..	..	..	[sprang up 19h.]
7	.. ..	..	..	..	71.5	87.0	..	62.3	..	18	E. wind all day ; less cold.
8	.. ..	..	..	..	69.4	..	..	68.0	24	..	SE. to E. wind from 6h.
8	Anusamad .. ..	..	..	2630	..	88.8	..	..	..	..	—
9	.. ..	..	..	..	58.0	..	..	52.5	..	..	Moderate E. wind all day ; no clouds, but visibility
9	Assarara	18 36	8 35	2615	..	85.0	..	..	..	..	[not good.]
10	.. ..	..	..	..	62.0	..	..	62.0	..	..	E. wind from 11h. became NW. at 16h. Some haze
10	Assode	18 27	8 29	2395	..	72.0	..	..	..	24	[all day.]
11	.. ..	..	..	..	63.0	..	..	62.3	25	..	No cloud except at sunset, when much Ci.
11	Afis	18 37	8 38	2540	..	80.5	..	..	..	..	E. gale from 19h. all night.
12	.. ..	..	..	..	69.2	..	..	68.0	..	..	No clouds except a little St. at sunset.
12	Fodet	18 47	8 37	2690	..	83.6	..	..	..	..	—
13	.. ..	..	..	..	73.0	..	..	..	..	..	From noon on more and more Ci. covering sky.
13	Tanutmolet .. ..	..	..	2310	..	80.4	..	..	..	..	—
14	.. ..	..	..	..	60.8	..	..	58.0	..	..	More and more Ci. from 14h. onward.
14	Iferuan	19 05	8 25	2190	..	82.0	..	..	..	..	—
15	.. ..	..	..	..	58.3	84.5	93.0	56.5	33	14	Very little breeze ; Ci. from noon onwards.
16	.. ..	..	..	..	57.0	84.0	90.0	55.8	40	19	Weather as yesterday.
17	.. ..	..	..	..	59.0	86.8	93.0	55.5	36	14	Clear day.

* Heights printed in italics have been computed in the Meteorological Office from the pressure readings by aneroid in conjunction with any other available data.
 † 1922 : Sling thermometer readings are given when available ; the readings in italics are from the sheltered thermometer (see p. 7).

Day.	Station.	Lat. N.	Long. E.	Height *	Temperature.				Relative Hu- midity.		Remarks.
					† 6h.	† 12h.	Max.	Min.	6h.	12h.	
Nov., 1922.				ft.	°F.	°F.	°F.	°F.	%	%	
18	.. .. .	..	..	..	58.3	86.0	96.0	57.8	40	16	Much Ci. from dawn onward.
19	.. .. .	..	..	..	59.6	83.0	..	56.8	41	25	SW. breeze afternoon.
20	.. .. .	..	..	..	60.0	85.4	..	57.0	36	26	Some squalls and dust-devils p.m.
21	.. .. .	..	..	..	63.4	87.0	96.0	60.0	45	35	SW. wind, very light a.m., moderate p.m.
22	.. .. .	..	..	..	69.0	86.6	95.0	66.8	34	31	Much Ci. and St. to N. and NW.
23	.. .. .	..	..	..	70.2	86.5	94.0	65.6	39	32	NW. wind; hot all day.
24	.. .. .	..	..	..	66.6	83.0	91.6	63.6	52	46	Ci. all over sky p.m.
25	.. .. .	..	..	..	67.0	80.0	..	62.0	62	..	Some Ci. all day.
26	.. .. .	..	..	..	49.0	..	..	48.0	..	..	Some Ci. all day; W. breeze all day from about 8h.
26	Areitun .. .. .	..	..	1960	..	79.0	..	..	..	..	..
27	.. .. .	..	..	..	43.0	..	..	43.0	..	..	Scarcely any cloud, but thin St. to W. at Sunset.
27	Agellal	18 43	8 10	2011	..	80.0	..	..	..	..	..
28	.. .. .	..	..	..	42.0	..	..	41.0	..	..	Light SW. breeze all day; no clouds.
28	Anuwisheran .. .. .	..	..	1990	..	82.0	..	..	..	..	..
29	.. .. .	..	..	..	63.0	..	..	..	..	..	SE. breeze; clear sky.
29	Garet .. .. .	..	..	1960	..	78.0	..	..	..	..	Calm from 15h. onwards.
30	.. .. .	..	..	..	59.0	..	..	58.8	..	..	Easterly breeze till sunset. No cloud except a little
30	Anu Maqaran.. .. .	..	..	2050	..	76.2	..	..	..	..	[Ci. at sunset.]
Dec., 1922.											
1	Anu Maqaran.. .. .	..	..	2050	43.0	..	..	42.0	..	..	No clouds; hot marching at times.
1	Tamenzaret .. .. .	..	..	2560	..	76.3	..	..	..	..	..
3	Auderas	17 38	8 25	2041	..	75.8	..	..	..	..	SE. wind, very light all day.
4	.. .. .	..	..	..	49.0	80.0	..	46.4	..	..	No cloud.
5	.. .. .	..	..	..	49.0	78.6	..	47.3	..	..	..
6	.. .. .	..	..	..	60.3	..	..	60.0	..	..	Moderate W. wind all day, clear sky sunset.
6	Arawat .. .. .	..	..	2600	..	68.6	..	..	..	..	..
7	.. .. .	..	..	..	38.8	..	..	37.0	..	..	Heavy low haze till 14h.; then cleared with Westerly
7	In Watsa .. .. .	..	..	2405	..	75.0	..	..	..	..	[wind.]
8	.. .. .	..	..	..	45.5	..	..	45.4	..	..	Ci. all day; W. wind from 9h. veering N.W. p.m.
8	In Delawin .. .. .	..	..	2110	..	77.7	..	..	..	..	..
9	.. .. .	..	..	..	..	..	..	53.0	..	..	..
9	Akaraq .. .. .	..	..	1760	..	79.2	..	..	..	..	Ci. lasted all night and all to-day.
10	.. .. .	..	..	..	53.7	..	..	52.5	..	..	Thin Ci. over all sky all day, cleared at sunset.
10	Eghalgawen	16 48	8 32	1720	..	79.3	..	..	..	..	..
11	.. .. .	..	..	..	..	..	..	61.5	..	..	..
11	Milen	16 29	8 29	1630	..	79.6	..	..	..	..	Some Ci. all day.
12	.. .. .	..	..	..	..	..	..	54.3	..	..	NE. wind with much sand and dust all day from 8h.
12	Anu Banka .. .. .	..	..	1600	..	71.5	..	..	..	..	..
13	.. .. .	..	..	..	53.0	..	..	52.0	..	..	Strong NE. wind all day; much dust in air.
13	Nr. Keta .. .. .	..	..	1585	..	64.0	..	..	..	..	..
14	.. .. .	..	..	..	49.0	..	..	48.0	..	..	NE. wind less strong; less dust.
15	Tiworshekaken .. .. .	..	..	1040	40.4	..	..	31.0	..	..	NE. wind less strong, a little Ci. all day.
15	Kidigi .. .. .	..	..	1440	..	65.6	..	..	..	..	..
16	.. .. .	..	..	..	39.0	..	..	37.0	..	..	NE. wind. Less cold; more normal weather.
16	Hannekar .. .. .	..	..	1475	..	71.0	..	..	..	..	..
18	Mazzia .. .. .	..	..	1515	..	72.2	..	..	..	..	Clear till 11h.; then haze from NE. and N.
19	.. .. .	..	..	..	53.8	..	..	49.0	..	..	NE. breeze; moderate to light; scarcely any haze.
19	Kallilua .. .. .	..	..	1410	..	71.3	..	..	..	..	..
20	.. .. .	..	..	..	44.0	..	..	37.0	..	..	NE. breeze; light all day; a little haze.
20	Zurawa .. .. .	..	..	1340	..	71.0	..	..	..	..	..
21	.. .. .	..	..	..	49.1	..	..	47.3	..	..	Light NE. breeze all day.
21	Takaka .. .. .	..	..	1410	..	70.4	..	..	..	..	..
22	.. .. .	..	..	..	38.0	..	..	37.5	..	..	Light NE. wind, no cloud.
22	Dambida .. .. .	..	..	1420	..	70.8	..	..	..	..	..
23	.. .. .	..	..	..	54.0	..	..	52.5	..	..	Light NE. breeze in fitful intervals. No cloud.
23	Beinaka .. .. .	..	..	1440	..	70.4	..	..	..	..	..
24	.. .. .	..	..	..	42.0	69.6	..	41.0	..	..	E breeze till 16h. No cloud.
25	.. .. .	..	..	..	54.0	..	..	46.0	..	..	NE. wind with much haze.
25	Kukasamu .. .. .	..	..	1450	..	72.2	..	..	..	..	No cloud.
26	.. .. .	..	..	..	45.6	..	..	45.0	..	..	Light NE. breeze. Thin high St. about all day.
26	Zongo .. .. .	..	..	1610	..	77.0	..	..	..	..	..
27	.. .. .	..	..	..	50.6	..	..	47.0	..	..	Light NE. wind; a good deal of Ci.
27	Dankwashi .. .. .	..	..	1440	..	75.6	..	..	..	..	..
28	.. .. .	..	..	..	40.8	..	..	40.0	..	..	Scarcely any wind. Much St. 4h.-12h. Much Ci.
28	Damberta .. .. .	..	..	1525	..	75.0	..	..	..	..	[all p.m.]
29	.. .. .	..	..	..	54.0	..	..	40.0	..	..	E. winds; some Ci. all day.
29	Nr. Kano .. .. .	..	..	1555	..	66.5	..	..	..	..	..
30	.. .. .	..	..	..	42.0	..	..	40.0	..	..	E. wind; some haze.
31	Kano .. .. .	..	..	2000	..	..	..	..	..	..	..

* Heights printed in italics have been computed in the Meteorological Office from the pressure readings by aneroid in conjunction with any other available data.

† 1922: Sling thermometer readings are given when available; the readings in italics are from the sheltered thermometer (see p. 7).

Day.	Station.	Lat. N.	Long. E.	Ht. *	Temperature.				Relative Hu- midity.		Cloud Amount.		Wind.		Remarks.	
					6h.	18h.	Max.	Min.	6h.	18h.	6h.	18h.	Dir.	Force		
				ft.	°F.	°F.	°F.	°F.	%	%			Dir.	Force		
May, 1927.																
22	Katsina	13 00	7 38	1660	..	86.5	..	..	..	41	..	..	..	Calm	Calm	Drops of rain 20h.
23	.. ..	..	..	..	72.5	80.5	86.9	71.6	95	69	10	..	..	Calm	Calm	Small tornado at 22h. 30m.
24	.. ..	..	..	..	71.4	83.5	89.3	73.6	83	57	10	5	..	SSW	1	18h. St. from SW., Ci. from NE.
25	.. ..	..	..	..	78.5	91.7	99.0	76.1	72	30	10	0	..	NE	2	10 St. at 7h., clearing by 9h.
26	.. ..	..	..	..	77.5	..	..	..	76	..	0	..	..	SW	2	Wind calm after 17h. 10m.
27	.. ..	..	..	..	85.3	83.5	99.0	82.3	41	62	0	10	..	SSE	2	Nly. squall 15h. 27m.
28	.. ..	..	..	..	74.5	89.5	91.0	73.6	79	42	8	0	..	Calm	Calm	Much Ci-Cu. a.m., clear p.m.
29	.. ..	..	..	..	81.5	..	99.0	79.1	73	..	0	..	..	SW	1	Heavy rain seen in distance.
30	.. ..	..	..	..	80.5	..	..	81.3	73	..	9	..	..	E	2	9/10 cloud till 10h., clearing later.
30	Dankaba	13 13	7 45	1470	..	92.2	..	..	..	43	..	..	..	..	..	..
31	.. ..	..	..	..	..	..	..	75.1	..	..	4	..	..	W	1	..
June, 1927.																
1	Dan Kama	13 15	7 48	1450	75.5	86.5	96.6	69.9	78	52	7	8	..	Calm	Calm	Scarcely any wind all day.
2	.. ..	..	..	..	79.2	80.5	98.5	71.1	78	54	0	..	..	SW	1	Dust storm about 18h.
3	Gazawa	13 32	7 57	1360	..	88.7	96.6	70.7	..	48	..	0	..	..	..	No heat flicker.
4	.. ..	..	..	..	76.0	..	..	74.7	83	..	0	..	..	SE	1	Clear a.m., 10 Nb. by 15h. 40m.; then
4	Tessawa	13 46	7 59	1330	..	79.7	..	..	..	66	..	10	..	..	..	[rain.
5	.. ..	..	..	..	..	..	..	..	..	..	5	..	..	..	..	Visibility very good all round, after
5	5 miles NNE. Tessawa	..	..	1260	..	72.5	..	..	..	78	..	..	..	..	..	[rain.
6	.. ..	..	..	..	71.3	..	..	67.6	93	..	1	..	..	S	1	St. 9 at 10h., clear by noon.
6	Urufan	14 05	8 06	1380	..	89.5	..	..	..	37	..	0	..	..	..	..
7	.. ..	..	..	..	80.7	96.5	..	72.3	71	30	0	..	..	..	..	..
8	.. ..	..	..	..	82.0	..	..	79.1	67	..	0	..	..	..	..	..
8	Giddan Yaro .. ..	..	..	1450	..	..	104.0	..	..	..	..	..	..	..	..	..
9	.. ..	..	..	..	75.5	..	98.2	73.1	80	..	0	8	..	..	..	..
10	Nr. Yagaji .. ..	..	..	1450	74.0	..	..	70.1	..	..	..	..	..	..	..	..
10	.. ..	..	..	..	..	89.5	99.2	..	50	..	..	..	..	..	..	..
11	Yagaji .. ..	..	..	..	78.7	..	..	79.3	67	..	..	..	..	W	1	..
11	Kurdidifi	14 31	8 28	1470	..	94.7	102.5	..	40	..	..	..	..	..	..	..
12	.. ..	..	..	..	80.1	..	..	76.1	69	..	6	..	..	SW	1	..
12	.. ..	..	..	..	..	91.5	98.0	..	33	..	1	..	..	..	..	..
13	Gangara	14 36	8 30	2057	..	89.0	93.5	80.6	65	31	10	3	..	SSW	3	SW
14	.. ..	..	..	..	81.5	92.9	100.4	80.3	61	33	10	8	..	..	..	..
15	.. ..	..	..	..	83.5	90.3	102.5	83.1	52	36	10	10	..	..	..	..
16	.. ..	..	..	..	81.9	91.5	102.7	80.1	54	39	1	0	..	W	1	SW
17	.. ..	..	..	..	81.0	94.5	102.0	80.6	53	21	1	3	..	WSW	2	SW
18	.. ..	..	..	..	77.5	77.3	101.9	76.9	60	77	9	10	..	W	1	W
19	.. ..	..	..	..	74.5	86.7	96.4	72.6	83	49	0	..	..	SW	1	..
20	.. ..	..	..	..	75.0	..	..	72.5	69	..	0	..	..	W	1	..
20	.. ..	..	..	..	..	92.0	..	..	32	..	2	..	..	..	..	..
21	Nr. Tagelal .. ..	..	..	1500	..	..	..	..	..	..	..	..	..	..	..	..
21	.. ..	..	..	..	77.7	..	..	73.6	63	..	..	..	..	W	1	..
21	Nr. Eliki .. ..	..	..	..	..	92.5	105.5	..	21	..	..	..	..	..	..	..
22	.. ..	..	..	..	73.5	..	..	73.6	65	..	0	..	..	..	..	..
22	Tinawgarakan	15 18	8 16	1500	..	98.3	105.5	..	16	..	0	..	..	..	..	..
23	.. ..	..	..	..	81.5	80.5	..	70.1	52	..	0	..	..	..	..	..
24	.. ..	..	..	..	74.6	93.5	102.0	..	37	10	1	..	..	..	..	..
25	.. ..	..	..	..	77.7	..	..	72.1	70	..	9	..	..	SW	2	..
25	Bush Camp, Tinawgarakan Valley.	..	..	1520	..	94.0	..	..	16	..	0	..	..	..	..	..
26	.. ..	..	..	..	83.5	98.0	103.0	..	45	18	1	0	..	SW	2	NW
27	.. ..	..	..	..	79.0	..	..	76.1	53	..	10	..	..	SW	1	..
28	.. ..	..	..	..	77.5	..	..	75.6	75	..	0	..	..	..	..	..
28	Yofaghazwa Valley	..	..	..	..	94.5	108.5	..	14	..	0	..	..	..	..	..
29	.. ..	..	..	..	80.5	..	..	79.6	48	..	2	..	..	SW	1	..
29	Desert Camp	..	..	..	..	93.0	..	..	37	..	1	..	..	..	..	..
30	Desert Camp	..	..	..	77.5	..	..	77.6	59	..	1	..	..	..	..	..
30	Tagedufat	16 06	8 24	1634	..	95.0	105.5	..	23	..	0	..	..	..	..	..

* Heights printed in italics have been computed in the Meteorological Office from the pressure readings by aneroid in conjunction with any other available data.

Day.	Station.	Lat. N.	Long. E.	Ht. *	Temperature.				Relative Hu- midity.		Cloud Amount		Wind.		Remarks.			
					6h.	18h.	Max.	Min.	6h.	18h.	6h.	18h.	Dir.	Force.				
July, 1927.				ft.	°F.	°F.	°F.	°F.	%	%								
1	Tagedufat ..	16 06	8 24	1634	80.0	..	110.6	..	47	..	4	..	..	..	Dust and rain storms afternoon.		
3	Milen ..	16 29	8 29	1630	..	..	..	..	..	..	0	..	Calm	..	Visibility very poor p.m.		
3	T'inwana ..	16 42	8 27	2218	..	89.5	..	..	37	..	..	..	SW	3			
4	81.5	96.8	101.6	75.1	47	17	0	0	W	I	Much dust from 16h. onward.			
5	86.5	97.0	103.4	87.7	40	24	0	0	W	I	Heavy Cu. round horizon 14h. 30m. to 17h.			
6	83.5	92.0	..	84.1	53	33	1	1	WNW	3	Wind velocity measured 800 ft./min. 13h.			
7	82.5	81.5	103.0	83.1	52	58	0	5	W	I	Squalls ceased just before 17h.			
8	77.5	93.5	100.0	76.6	63	25	0	6	Calm	NW	2	Visibility poor all day.		
9	82.5	94.0	101.5	82.4	..	34	0	9	W	I	Storm p.m. preceded by cloud of sand.			
10	83.5	90.9	102.0	82.6	45	33	0	0	W	I	Last night still and hot.			
11	82.5	93.5	94.5	83.9	52	32	5	0	SW	I	Dull sunset behind grey St.			
12	82.5	..	..	80.3	48	..	2	..	NW	I	16h. 15m. sandstorm from NE.			
12	Nr. Agades..	..	..	..	..	93.5	..	..	..	28	..	9	..	SW	2		
20	Azzal ..	..	..	..	..	98.0	..	..	..	37	..	0	..	WNW	2	Pale yellow sunset.	
21	80.7	..	..	82.1	15	..	8	..	W	I	Very hot gusts of wind from E. 12h. [to 13h.]			
21	Dabaga ..	..	..	2110	..	97.5	..	..	..	11	..	3	..	ENE	1		
22	80.5	..	..	69.0	66	..	..	..	Calm	..	Shower 12h. 15m. to 12h. 30m.			
22	Aghejabjab..	..	..	2250	..	88.5	..	..	..	37	..	3	..	Calm	..		
23	78.8	..	..	73.7	55	..	8	..	SW	1	Showers 16h. to 18h. 45m.			
23	Tilisdak ..	..	..	2380	..	83.5	..	..	..	..	..	..	..	..	..
24	78.0	..	..	..	..	67	..	..	..	..	..	16h. storm over Todra, passed south.		
24	Auderas ..	17 38	8 25	2641	..	87.3	..	..	..	33	..	..	..	..	..
25	82.2	90.0	107.3	75.1	45	31	7	2	Calm	Calm	Sun heavily veiled at noon.			
26	79.0	94.5	109.0	76.3	51	23	0	8	W	I	Dust devil from west p.m.			
27	79.5	94.0	104.8	79.5	57	17	0	4	NW	I	Nb. from north-east passed south 16h.-17h.			
28	79.9	87.5	101.2	80.0	55	33	0	1	SW	I	SSW	3	Few drops rain 13h. 30m.	
29	77.5	82.5	96.0	74.3	59	38	10	4	Calm	W	3	Storm 12h.; wind measured 25.8 [m.p.h.]		
30	71.5	88.5	97.2	69.7	71	16	0	9	Calm	N	I	18h. heavy dark cloud, no rain visible.		
31	75.5	89.3	..	75.1	67	31	8	..	W	3	WNW..	..	Very clear at 6h.	
Aug., 1927.																		
1	Auderas ..	17 38	8 25	2641	77.5	87.5	102.0	75.3	63	..	1	9	NNW	I	E	5	Thunderstorm and rainbow 16h.	
2	79.7	84.5	95.5	..	60	47	0	..	W	I	SW	1	Storm; showers 11h. 50m. to 13h. 30m.	
3	76.5	72.5	93.2	74.1	60	78	9	10	Calm	W	I	..	Showers p.m.	
4	70.5	78.0	99.0	..	93	65	6	8	SW	I	SW	I	Rain storms all day in various parts.	
5	75.5	77.0	93.5	78.7	78	77	1	7	W	I	Calm	..	Storm; rain 13h. 35m. to 14h. 45m.	
6	70.0	73.5	87.4	68.1	85	80	2	10	Calm	Calm	..	..	Storm from E. 16h. 30m.	
7	76.5	76.1	86.9	71.9	69	75	..	..	..	..	..	..	Sharp showers 11h. 50m. to 17h. 30m.	
8	71.3	85.2	93.0	79.6	65	44	0	..	Calm	..	..	..	Detached Cu. from E. all day.	
9	76.2	76.3	93.0	73.5	74	..	0	10	NE	I	SE	1	Light showers from NE. p.m.	
10	75.1	75.3	98.5	73.3	75	73	3	10	Calm	..	..	..	17h. mist came down over south flank of Todra.	
11	73.2	91.5	99.5	72.1	57	29	8	8	E	3	NE	2	Very little breeze all day.	
12	73.5	89.5	98.5	69.9	70	27	0	1	Calm	ESE	2	..	Considerable dew 6h.	
13	74.5	79.5	95.5	72.7	72	57	0	4	Calm	W	1	..	Storm from E. p.m.	
14	72.2	78.0	93.5	71.6	..	..	2	4	E	I	NE	3	Rainstorm p.m.	
15	75.0	80.0	100.0	70.1	65	..	2	8	Calm	..	..	..	Storm 16h. 30m.	
16	73.0	84.1	95.5	71.1	67	33	7	..	Calm	NW	1	..	Grey sunset behind Cu. and St.	
17	73.5	79.3	96.5	70.1	70	63	4	9	Calm	Calm	..	..	River began running 20h. 30m.	
18	73.5	76.1	94.0	70.6	78	66	9	9	NE	I	Calm	..	Storms from E. and NE. p.m.	
19	74.5	82.0	96.5	68.0	66	43	0	..	Calm	..	..	..	p.m. biggest storm yet seen.	
20	80.0	91.5	94.5	74.1	43	9	0	..	W	I	..	..	Very hazy all day.	
21	77.5	84.5	100.0	74.1	58	31	..	..	NW	2	SW	2	Hot day till wind changed at 16h.	
22	77.5	77.5	94.6	71.1	63	67	0	..	N	I	NW	1	..	Both rivers running by 16h.
23	72.5	..	96.0	66.0	65	..	3	..	NW	I	NW	1	..	Rain storm p.m.
24	76.0	81.5	97.0	69.6	65	45	0	..	NW	I	N	1	..	Rain p.m.
25	75.8	74.5	92.0	..	66	..	1	..	Calm	..	..	..	Rain late afternoon and evening.	
26	71.5	76.5	94.0	69.0	74	63	..	9	Calm	N	1	..	Showers p.m.	
27	71.5	77.5	95.0	67.0	81	68	0	..	Calm	Calm	..	..	Showers 12h. 50m. to 16h.	
28	71.0	75.9	92.0	67.5	84	69	1	0	Calm	N	1	..	Heaviest dew yet seen.	
29	69.1	84.5	95.0	68.5	89	36	2	0	Calm	SE	2	..	Very hazy p.m.	
30	75.5	91.3	99.0	71.6	66	17	0	1	E	I	E	2	..	Hazy p.m.
31	75.5	91.8	..	72.8	62	12	1	..	Calm	Calm	..	..	Very clear evening.	

* Heights printed in italics have been computed in the Meteorological Office from the pressure readings by aneroid in conjunction with any other available data.

Day.	Station.	Lat. N.	Long. E.	Ht. *	Temperature.				Relative Humidity.		Cloud Amount.		Wind.		Remarks.			
					6h.	18h.	Max.	Min.	6h.	18h.	6h.	18h.	Dir.	Force				
																°F.	°F.	°F.
Sept., 1927.				ft.	°F.	°F.	°F.	°F.	%	%								
1	Auderas	17 38	8 25	2641	80.5	90.2	104.0	77.1	18	13	4	..	Calm	E	3	Scarcely any cloud all day.		
2	..	..	..	..	77.5	79.0	98.5	73.6	56	59	1	3	E	Calm	2	Showers p.m.	
3	..	..	..	..	74.5	82.5	94.0	68.0	71	41	10	10	Calm	Calm	..	Showers 15h. 30m. to 17h.	
4	..	..	..	..	71.0	94.5	102.5	65.5	81	18	10	10	Calm	E	2	Clear sky till noon.	
5	..	..	..	..	77.0	..	..	71.1	43	..	..	..	Calm	..	..	Thick haze all day, visibility often lower	
5	Tegbishi	..	..	2860	..	91.5	..	..	..	17	..	..	..	E	2	[than 1 mile.	
6	..	..	..	..	72.5	..	..	69.0	43	..	..	..	Calm	..	..	Haze dawn to sunset, less thick than	
6	Towar	17 36	8 33	3327	..	92.2	..	..	..	15	..	..	..	..	..	[yesterday.	
7	..	..	..	..	83.0	90.0	95.0	64.5	19	36	..	..	SE	3	NE	2	Haze cleared by 9h.
8	..	..	..	..	83.0	88.0	94.5	63.5	18	19	0	..	NE	2	SE	1	Very hazy in afternoon.
9	..	..	..	..	82.2	83.0	94.0	61.0	29	..	8	10	Calm	Calm	..	..	Showers 17h. 30m. to 18h. 45m.
10	..	..	..	..	73.1	..	..	65.0	67	..	4	..	N	1	..	..	Shower p.m. then cleared, no cloud by
10	Adkakit	..	..	2740	..	86.0	98.0	..	..	36	..	5	..	Calm	Calm	..	[19h.
11	..	..	..	..	68.5	..	..	57.0	45	..	0	..	Calm	..	..	..	..
11	Teloas	..	..	..	..	88.5	..	..	..	9	..	..	..	Calm	..	..	..
12	..	..	..	..	72.5	..	..	59.3	63	..	2	..	Calm	..	..	..	Extraordinarily clear evening.
12	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	Very clear early; Some Nb. 16h. to
12	Emilial	..	..	3667	..	88.0	98.0	..	..	7	..	0	..	E	1	..	[17h. 30m.
13	..	..	..	..	72.0	..	..	55.0	27	..	0	..	Calm	..	..	..	Hot day, very little air moving, but
13	Wellek	..	..	3090	..	89.0	..	..	..	16	..	0	..	SE	2	..	[clear.
14	..	..	..	..	73.5	..	..	62.0	27	..	9	..	Calm	..	..	..	Much glare to-day. Drops of rain at
14	Telleichina	..	..	3656	..	87.0	..	..	..	16	..	..	..	E	2	..	[14h.
15	..	..	..	..	76.0	..	..	70.1	24	..	8	..	Calm	..	..	..	Cloudy on and off all day.
15	Tintaralle	18 27	8 56	3149	..	86.0	..	..	..	25	..	..	..	..	..	..	Drops of rain 11h.
16	..	..	..	..	78.8	86.0	99.0	72.1	34	27	3	5	Calm	N	1	..	13h. thunder to W. and N.W
17	..	..	..	..	82.2	88.5	..	65.0	27	9	0	0	NE	1	NE	1	Slight zodiacal light 18h.
18	..	..	..	..	74.2	..	..	69.6	17	..	0	..	NE	1	..	..	Thin Ci. over all sky all day.
18	Main Valley	..	..	2820	..	85.5	..	..	..	13	..	..	..	..	NE	1	..
19	..	..	..	..	64.7	..	..	55.0	45	..	0	..	Calm	..	..	..	Some rain 16h.-16h. 30m.
19	Agaragar Valley	..	..	2770	..	87.2	..	..	..	63	..	..	..	NE	1	..	..
20	..	..	..	..	68.5	..	..	64.0	45	..	..	..	Calm	..	..	..	Hot travelling.
20	Iberkom	..	..	..	..	91.5	..	..	..	17	..	8	..	NE	2	..	..
21	..	..	..	..	83.5	..	..	60.5	16	..	0	..	ENE	3	..	..	Very hazy day.
21	Iferuan	19 05	8 25	2190	..	91.5	..	..	..	7	..	0	..	Calm	..	..	..
22	..	..	..	..	78.0	94.3	114.0	76.6	20	19	0	2	Calm	NE	1	..	Very hot day.
23	..	..	..	..	76.3	89.2	109.0	74.1	51	27	2	0	Calm	Calm	..	..	Showers 14h. to 15h. 30 m.
24	..	..	..	..	72.5	92.7	108.0	73.1	53	15	0	3	Calm	Calm	..	..	Visibility exceptionally good all day.
25	..	..	..	..	77.5	89.9	107.0	74.1	59	..	2	9	Calm	E	3	..	Showers 11h. 30m. to 17h.
26	..	..	..	..	73.4	93.9	107.0	70.1	61	16	..	0	Calm	Calm	..	..	Very clear 18h.
27	..	..	..	..	74.5	95.1	110.0	71.1	48	14	0	0	Calm	ENE	2	..	Very clear at sunset.
28	..	..	..	..	72.1	93.5	110.0	71.1	34	9	0	0	Calm	ENE	2	..	Visibility good 18h.
29	..	..	..	..	82.5	96.5	113.0	80.1	12	8	0	0	Calm	..	..	..	No cloud all day.
30	..	..	..	..	68.5	..	..	65.5	34	..	0	..	Calm	..	..	..	Not a trace of cloud all day.
30	Tegidda Mellen	19 12	8 21	2150	..	91.0	102.0	..	..	8	..	0	..	NE	3	..	..
Oct., 1927.																		
1	Tegidda Mellen	19 12	8 21	2150	73.5	92.5	107.0	71.1	16	7	0	0	NE	1	NE	3	..	Visibility very good 18h.
2	..	..	..	..	74.5	93.5	102.5	69.6	21	8	0	5	Calm	NE	2	..	High cloud during day.
3	82.5	88.5	100.0	75.6	27	25	9	8	ESE	1	WNW	1	..	Showers 14h. 30m. to 14h. 50m.
4	78.3	92.5	102.5	76.1	36	12	6	5	NE	2	NE	3	..	Visibility very poor all day.
5	..	..	..	..	73.5	93.5	103.0	71.6	24	9	0	0	Calm	NNE	3	..	Very hazy all day.
6	77.3	93.5	103.0	72.1	18	8	NE	2	N	1	..	Scarcely any breeze all day.
7	79.3	91.5	102.0	74.1	26	16	NE	3	N	2	..	Strong gusts at times 8h.-16h.
8	79.5	93.0	..	73.1	26	19	6	7	NE	3	NW	2	..	A little rain 19h. to 19h. 10m.
9	78.0	91.5	111.0	68.0	25	12	N	2	NE	1	..	Detached Cu. from ENE. 11h.-17h.
10	76.5	92.5	..	73.1	21	14	NE	2	NNE	1	..	Sky covered with St. nearly all day.
11	79.5	92.0	..	73.6	23	14	2	1	N	1	N	1	..	Showers seen falling to E.
12	79.0	89.7	101.0	77.1	17	15	..	0	..	Calm	Cu. and Nb. from NE. 11h. onwards.
13	76.5	87.0	..	77.1	21	25	7	3	..	ENE	3	Rain-storm 10h. 30m.
14	75.5	89.7	100.0	72.1	34	20	N	2	NE	2	..	No cloud.
15	81.8	90.3	102.0	76.1	21	14	NE	2	NNE	2	..	Dust storm from NE. 11h. 30m
16	..	..	..	..	73.5	88.0	93.2	70.1	27	14	..	..	NNE	1	..	..	No cloud.
17	72.5	91.5	109.0	70.6	25	19	0	..	Calm	17h. appearance of rain to E.
18	79.5	94.5	106.0	80.1	29	14	4	7	ENE	1	S	3	..	Whirlwind struck camp 15h.
19	75.5	90.5	106.0	75.1	29	12	4	NE	2	12h.-17h. wind NE. force 5.
20	77.3	88.7	..	75.6	37	14	NE	6	NE	1	..	Strong NE. wind 4h.-6h.
21	75.0	NE	2	Strong NE. wind morning.
22	Aberkot Valley	71.5	23	Fresh NE. wind all day.
23	Tarazit Pool	2520	..	86.5	13	War n night.
24	77.5	21
25	75.5	88.5	14	8
26	0
27	80.0	17	..	5
28	Desert	72.5
29	Desert N. of Tamgak	68.5	45	NE	5	Fresh E. wind all day. Very cold night.
31	Iferuan	19 05	8 25	2190	63.0	82.5	98.0	..	49	17	14h. sky almost covered with St from [SW.

* Heights printed in italics have been computed in the Meteorological Office from the pressure readings by aneroid in conjunction with any other available data

Day.	Station.	Lat. N.	Long. E.	Ht. *	Temperature.				Relative Hu- midity.		Cloud Amount		Wind.		Remarks.	
					6h.	18h.	Max.	Min.	6h.	18h.	6h.	18h.	Dir.	Force		
Nov., 1927.				ft.	°F.	°F.	°F.	°F.	%	%						
1	Iferuan	19 05	8 25	2190	59.5	81.0	105.0	59.0	55	19	0	0	..	N	I	—
2	..	..	..	..	62.5	78.0	102.5	57.0	41	20	0	1	..	..	..	—
3	..	..	..	..	68.0	..	..	64.0	30	..	2	..	..	..	..	—
3	Anefok	..	..	1960	..	78.5	..	..	..	19	10	..	ENE	4	..	A few drops of rain in night.
4	..	..	..	..	70.3	..	..	69.0	28	..	9	..	NNE	3	..	A few drops of rain 7h. 20m.
4	Tedckel	..	..	1750	..	77.2	..	..	..	23	0	..	E	2	..	—
5	..	..	..	..	70.5	..	..	65.5	35	..	..	..	..	..	..	No cloud.
5	Lower Taruei	..	..	1620	..	..	..	..	..	..	0	..	..	..	..	—
6	..	..	..	..	64.5	..	..	55.0	37	..	0	..	..	..	..	No cloud all day.
6	Arli	19 00	7 38	1543	..	83.1	99.0	..	17	..	0	0	..	..	..	—
7	..	..	..	..	64.8	84.5	94.5	61.0	33	10	0	0	..	ENE	3	No cloud.
8	..	..	..	..	67.7	84.0	98.0	54.0	27	10	0	0	..	ENE	3	No cloud.
9	..	..	..	..	74.9	81.0	93.5	..	18	15	0	0	..	NE	3	No cloud.
10	..	..	..	..	65.5	..	..	64.0	19	..	0	..	NE	I	..	No cloud.
10	Tagellalt	..	..	1550	..	82.1	..	..	10	..	0	0	..	NE	2	—
11	..	..	..	..	64.5	..	..	55.0	33	..	0	..	..	..	..	Much mirage.
11	Efenghalen	..	..	..	..	79.5	..	..	12	..	0	0	..	NE	I	—
12	..	..	..	..	59.3	..	..	48.0	21	..	0	..	..	..	..	—
12	Adar Valley	..	..	..	..	77.5	98.5	..	23	..	0	..	..	..	..	Strong zodiacal light 18h.
13	Desert Camp	..	..	1400	53.0	..	..	46.0	25	..	0	..	..	..	..	Mirage 6h. 30m. till sundown.
13	D. Camp	..	..	1310	..	77.2	..	..	12	..	0	0	..	..	..	—
14	..	..	..	..	..	..	..	45.0	..	..	0	..	..	..	..	Mirage 6h. 30m. to 15h.
14	Inallaren Valley	18 16	..	..	..	77.3	..	..	13	..	0	0	..	NE	I	—
15	D. Camp	..	..	1270	58.5	..	..	51.0	22	..	0	..	..	..	..	Mirage began 7h. 30m.; very strong to
15	Buttel	18 11	6 11	1149	..	79.0	..	..	12	..	0	0	..	..	..	[S. 13h.]
16	..	..	..	..	58.0	81.0	100.0	56.0	27	17	0	0	..	..	..	High zodiacal light 18h.
17	..	..	..	..	59.7	..	..	50.0	25	..	0	..	..	..	..	No cloud.
17	D. Camp	..	..	1210	..	76.5	..	..	17	..	0	0	..	..	..	—
18	..	..	..	..	57.7	..	..	49.0	27	..	0	..	N	I	..	18h. slight cloud to W. first seen since
18	D. Camp	..	..	1160	..	78.5	..	..	14	..	0	0	..	NNE	1	[leaving Air.]
19	..	..	..	..	58.5	..	..	49.0	26	..	0	..	NNE	I	..	Hazy all day from 7h.
19	In Nuggaren Wells	17 59	5 18	1270	62.0	81.0	..	55.0	32	..	0	..	..	..	..	Day slightly hazy.
20	D. Camp	..	..	1090	..	81.1	..	..	18	..	0	0	..	NE	I	—
21	..	..	..	..	60.8	..	..	52.5	31	..	2	..	E	I	..	—
21	Nr. Indunan	..	..	..	..	77.3	..	..	20	..	0	0	..	..	..	—
22	..	..	..	..	60.5	..	..	48.0	28	..	8	..	..	..	..	Some mirage mid-day.
22	In Aridel	17 45	4 25	1152	..	73.0	..	..	27	..	0	0	..	..	..	—
23	..	..	..	..	61.0	76.9	86.9	57.0	26	22	2	0	..	..	..	Haze at sunset.
24	..	..	..	..	54.5	..	..	53.5	55	..	9	..	..	..	..	—
24	Tiriken Valley	..	..	1170	..	76.3	..	..	24	..	3	..	..	..	..	—
25	..	..	..	..	53.9	..	..	47.0	38	..	9	..	..	..	..	6/10-7/10 cloud all day.
25	Nr. Temakkas	..	..	..	..	81.3	..	..	17	..	7	..	..	..	..	—
26	Temakkas	..	..	..	59.3	..	..	56.0	31	10	..	..	NE	I	..	Sun veiled nearly all day.
26	D. Camp	..	..	1230	..	76.5	..	..	16	..	..	..	..	..	..	—
27	..	..	..	..	56.5	..	..	51.5	22	..	..	..	NE	I	..	Cool day marching.
27	Tanekert Well	17 49	3 11	1205	..	74.5	..	..	12	..	..	..	..	..	..	—
28	..	..	..	..	54.5	73.9	96.0	46.0	19	15	10	..	NNE	2	..	Much mirage to N. 12h. to 15h.
29	..	..	..	..	56.2	..	..	47.0	22	..	9	..	N	I	..	Sky covered with St. all day.
29	Nr. Tesa tan Tiklatin	..	..	1450	..	78.5	..	..	19	..	10	..	..	..	..	—
30	..	..	..	..	64.3	..	..	61.0	17	..	7	..	NNW	2	..	Sky completely overcast all day.
30	Akalu Valley	18 08	2 16	1480	..	72.9	..	..	20	..	10	..	..	..	..	—
Dec., 1927.																
1	Akalu Valley	..	..	..	67.0	..	..	56.0	21	..	10	..	..	..	..	10/10 St. nearly all day.
1	Upper Akalu	..	..	1530	..	78.7	..	..	19	..	10	..	..	..	..	—
2	..	..	..	..	66.5	..	..	56.5	21	..	10	..	..	..	..	Cool and cloudy all day.
2	D. Camp	..	..	1500	..	75.5	..	..	34	..	..	..	..	..	..	—
3	..	..	..	..	64.5	..	..	55.5	53	10	..	..	..	..	..	Cold trekking; low St. all day.
3	D. Camp	..	..	1650	..	75.1	..	..	37	..	..	..	..	..	..	—
4	..	..	..	..	63.7	..	..	59.0	62	10	..	..	NE	3	..	10/10 St. all day; drops of rain 16h.
4	D. Camp	..	..	1480	..	69.5	..	..	57	..	..	..	..	NE	2	[30m.]
5	..	..	..	..	66.3	..	..	60.5	66	10	..	..	ENE	I	..	10/10 cloud all day.
5	Kidal	18 26	1 21	1520	..	75.5	..	..	51	..	..	..	..	..	..	—
6	..	..	..	..	63.5	71.5	94.0	..	78	48	8	10	..	..	..	—
7	..	..	..	..	58.1	..	..	..	76	..	2	..	SW	I	..	—
7	Bush Camp	..	..	1360	..	71.5	..	..	48	..	1	..	..	..	..	—
8	..	..	..	..	58.0	..	..	51.0	53	..	9	..	E	I	..	—
8	Camp	..	..	1320	..	71.5	..	..	48	..	2	..	..	NW	2	—
9	..	..	..	..	59.0	..	..	47.0	54	10	..	..	NE	I	..	—
9	Camp	..	..	1160	..	68.5	81.8	..	41	..	1	..	..	..	..	—
10	..	..	..	..	49.0	..	..	41.0	54	..	3	..	..	..	..	—
10	Camp	..	..	1090	..	75.5	86.9	..	21	..	0	..	..	..	..	—
11	..	..	..	..	58.0	79.5	93.0	..	31	11	8	3	NE	I	..	Lightning all round horizon after 18h.
12	..	..	..	..	63.0	..	..	57.0	40	..	9	..	..	..	..	—
12	Camp	..	..	1050	..	79.5	..	..	25	..	10	..	..	..	..	—
13	..	..	..	..	67.0	..	..	60.0	51	..	..	..	W	I	..	Sky covered with St-Cu. most of day;
13	Intaset	..	..	1010	..	77.5	..	..	59	..	9	..	..	..	..	spots of rain about 16h.
14	Camp	..	..	..	56.5	..	..	49.0	78	..	..	..	N	I	..	—
14	Camp	..	..	1110	..	76.5	..	..	44	..	..	..	..	NE	I	—
15	..	..	..	..	60.5	..	..	48.0	47	..	10	..	N	2	..	—
16	Burem on Niger	..	..	886	..	..	..	..	..	..	..	..	..	..	..	—

* Heights printed in italics have been computed in the Meteorological Office from the pressure readings by aneroid in conjunction with any other available data.