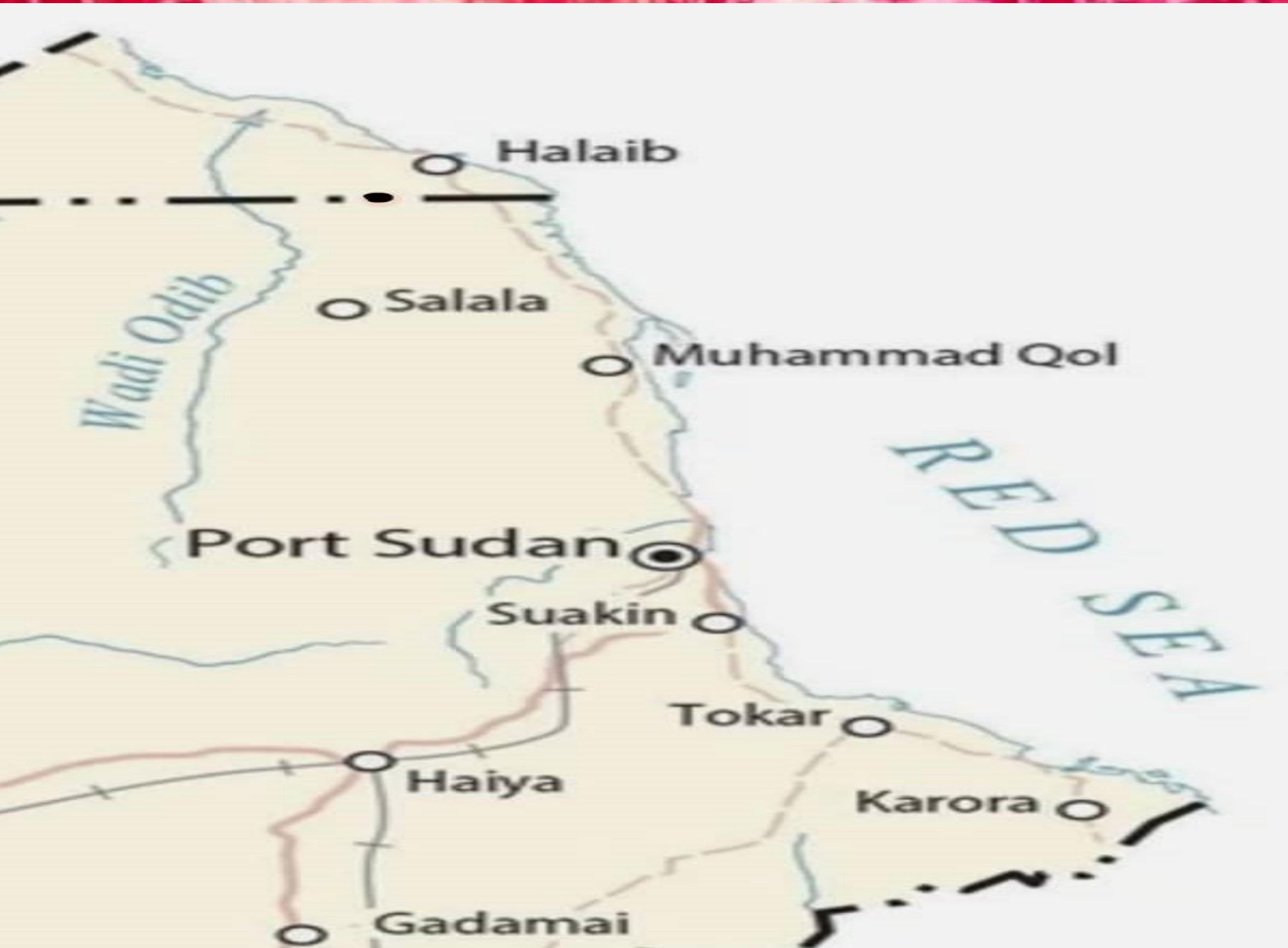


The Unique Climate of the Red Sea Region of The Sudan



Professor Mahdi Amin Eltom

2025

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**The Unique Climate of
the Red Sea Region of
The Sudan**

By

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لا يسمح بإعادة إصدار هذا الكتاب أو أي جزء منه أو تخزينه كنسخة إلكترونية أو نقله بأي شكل من الأشكال دون إذن خطي مسبق من المؤلف والناشر

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1- The Physical Setting

The Red Sea Region is a unique area in terms of its physical setting and its climatic characteristics. It is also an area of internal - as well as external - climatic contrasts.

The physical character of the area is dictated by:

1. The presence of the Red Sea as an adjacent body.
2. The Red Sea hills as an effective physical barrier.
3. The coastal plain as a narrow flat surface that lies under the direct influence of both the Sea to the east and the hills to the west.

The Red Sea as a water body acts as a moderating element as well as a source for water vapour. It is a relatively narrow water body that runs from North West to South East with an average width of around 400 kilometers. The moderating effect of the Sea arises from its nature as a permanent water body free from both warm and cold ocean currents and physically connected with the warm waters of the Arabian Sea on the one hand, and the temperate waters of the Mediterranean Sea on the other.

Regarding its nature as a source of water vapour, this stems from the fact that it lies more or less wholly within the low latitudes,

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as well as from the fact that it lies in a position that allows significant movement of on-shore winds throughout the year. This provides a mechanism for transporting water vapour from over the sea into the coastal plain and the near-by hilly area.

On the other hand, the Red Sea Hills represent a very dominant feature in the area. They form part of the Great African Rift Valley and they run parallel to the coastline in a general North West to South East direction. This general orientation allows them to act as an effective physical barrier in the face of both the permanent and the season-al winds that brush the Red Sea region. So all the on-shore winds approaching from the inland, are forced to ride above these mighty hills that have an average altitude of around 3000 feet but with some higher peaks and a few wind gaps especially in the South. Except where such gaps are found, the Red Sea hills tend to produce a significant orographic effect that might bring about cloud formations of different intensities on the wind-ward slopes, if the winds involved are laden with moisture. This automatically brings about rain shadow effect on the lee-ward slopes. However, if these winds are dry, then the orographic effect of the hills becomes confined to the production of lower temperature levels that normally

reflect a strong negative correlation with altitude. So the Red Sea hills in their capacity as physical barrier tend to play a very important role in determining the thermal characteristics as well as the precipitation potentialities of the Red Sea Region.

The third important component of the physical setting of the region under consideration is the coastal plain. This is a narrow confined plain at whose eastern side lies the waters of the Red Sea, and at whose Western side rise sharply the Red Sea hills. Thus within a very short distance the altitude changes from the zero level of the sea to about 3000 to 4000 feet above the mean sea level. This makes the climatic conditions over the coastal plain strictly controlled and determined by the nature and effects of the nearby sea and hills. This also allows the coastal plain to, more or less, avoid the direct effect of the inland conditions, except perhaps over the Southern part of the coastal plain where the existence of a wind-gap in the hills in the vicinity of Tokar allows some of the inland effects to be felt occasionally on the coast and the maritimal effects may also follow the same passage and bring about noticeable maritimal effects over the inland areas that lie in relatively close proximity to the Western slopes of the Red Sea hills.

2- Temperature

Being confined between latitudes 18° - 23° North, and longitudes 33° - 39° East, this makes the region under consideration to lie wholly within the Tropical zone with its characteristic high temperatures. However, here also the region tends to have its own peculiarities and contrasts. The hills, as expected, experience the lowest mean annual temperatures in the country and the lowest summer temperatures as well. This is a direct consequence of the altitudinal effect of the hills and it may be exemplified by the case of Erkowit whose mean annual temperature is 22°C and whose mean monthly temperature during the summer is around 27°C , which makes it in summer significantly cooler than the rest of the country except perhaps for the Southern part of the Sudan, where some of the border stations may experience comparable temperature levels in summer but normally experience higher temperatures during the winter season and hence such Southern stations are said to experience their summer during the winter season!

Anyway, the moderate temperature conditions over Erkowit and the other hilly areas make this part of the country suitable for

the development of a summer resort. It is in fact the only summer resort in the country.

In contrast to this, we find that the plains that lie just South of the Red Sea hills represent the hottest part of the country where the mean annual temperature fluctuates around 32 °C. Here the temperatures reach their highest levels during the summer season. This leads to the development of a seasonal thermal low which is known as the "Sudan thermal low", whose center tends to migrate North and South following the apparent migration of the over-head sun. The existence of this thermal low could be attributed to the nature of the soil as well as to the existence of extensive plains in proximity to the massive Ethiopian plateau.

In between the moderate conditions on the hills and the extremely hot conditions on the Southern plain lands, we find that the mean annual temperature fluctuates around 30 °C over the central and Northern parts of the coastal plain. The moderating effect of the Sea reduces considerably the seasonal thermal contrasts over the coastal plain and so here a rather limited annual range of temperature may be noticed, but temperatures as high as 36 °C may be experienced at Port-Sudan during the months of July and August.

Taking the region as a whole we find that January is the coldest month while June and July are the hottest months. June is usually the hottest month over the Southern half of the region while July is the hottest month over the Northern half. On the other hand, all the annual and monthly isotherms tend to follow a pattern that reflects the moderating effect of the sea as well as the altitudinal effect of the hills and hence they tend to be deflected as they approach the sea or the hills. Over the isolated peaks, however, a distinct cellular pattern is noticed. This cellular pattern is also observed around the center of the "Sudan thermal low" during the summer season.

3- Pressure and Winds

The location of the Red Sea Region on the Eastern side of the Northern part of tropical Africa brings it within the influence of the permanent sub-tropical high pressure belt as well as under the influence of the seasonal pressure systems that develop over both the Sahara desert and the Arabian peninsula. This makes most of the region to witness a radical change in the pressure conditions during the course of the year resulting in a complete wind-reversal especially over the Central and Southern parts of the region.

Due to the presence of the region to the South of the Centre of the permanent sub-tropical high-pressure belt, we find that the prevailing winds here are the Trade winds that normally approach from a northerly or a north-easterly direction. The flow of these winds is intensified considerably during the winter season as a result of the development of a seasonal high pressure system over the eastern part of the Sahara desert. Being in the Northern hemisphere, this seasonal high pressure system creates a wind-motion with a clockwise pattern and thus the winds generated at the eastern side of the system are generally northerly or north-easterly winds. These are

the winds that reach the Red Sea Region during the winter and since their direction coincides with the prevailing winds, we find that the winter season witnesses a noticeable intensification in the winds blowing from the North and the North-East.

During the same winter season, and as a result of thermal conditions similar to those responsible for the creation of the Sahara high pressure, or anticyclonic system, a distinct seasonal high pressure system develops over the South-Western part of the Arabian Peninsula. The development of a clockwise winter pattern around this Arabian system allows the Sudanese Red Sea Region to receive winds with a strong Southerly and South-Easterly components. Consequently, the region under consideration tends to receive North to North-Easterly as well as South to South-Easterly winds during the winter season as a result of the existence of two seasonal high pressure systems, namely the Sahara and the Arabian ones.

The two high pressure systems tend to create a pressure-trough over the waters of the Red Sea. The trough is normally marked with a discontinuity line or convergence belt which some climatologists used to describe as a front. However, the weak thermal and humidity

contrasts between the two air masses involved do not allow the development of a front, if we use the word "front" in its strict classical context.

The slope of the discontinuity line does not maintain a constant direction since the direction of that slope is always subject to the actual position, intensity and orientation of the two anticyclonic systems whose interaction produces the discontinuity line. Consequently, the line of discontinuity might at one time slope upward in the direction of the Equator while at another time it might be sloping in the direction of the Tropic of Cancer. But in all cases it does not act as a belt of frontal convergence and thus it does not produce any frontal effects over the Red Sea and its vicinity.

The existence of these pressure systems during the winter season creates conditions favourable for the attraction and passage of cold-fronts approaching from over the Mediterranean Sea. The frequency of these cold fronts over the Red Sea Region increases as the Sahara anticyclonic system intensifies. Although those fronts are originally rain-producing systems, yet they hardly contribute to the precipitation of the region since they normally lose their moisture content long before reaching the region and thus their effect

becomes confined to a temporary but noticeable drop in the temperature levels, possibly associated with dust storms triggered by the relatively active winds following the front.

Also for reasons associated with the distribution of the winter atmospheric pressure over the Sahara, the Middle East and Central Asia, we find that the Red Sea Region occasionally falls under the influence of cold air masses originating in Central Asia. This brings about an enormous drop in the temperature levels. Such cold air masses normally approach from a north-easterly direction and their passage over the waters of the Red Sea introduces a moderating effect.

As the summer season approaches, the two high pressure systems weaken and eventually disappear completely together with their resultant weather conditions. They are even replaced with seasonal low pressure systems which produce the "Sudan thermal low" and the "Arabian thermal low". During the peak of the summer season these lows merge into an extensive low pressure belt that covers the entire Sahara desert and the Arabian Peninsula, leaving the relatively cool waters of the Red Sea to form a weak pressure ridge. These changes bring the northern part of the Red Sea region

under the effect of the prevailing north-easterly trade winds, while the central and southern parts of the region come gradually under the influence of the south-west monsoonal winds. The advanced position of these monsoonal winds is marked by the Inter-Tropical convergence Zone (I.T.C.Z.). This brings about a complete reversal in the direction of the winds over the central and southern parts of the region. So these latter areas receive south-westerly winds during the summer season while during the winter season they lie under the influence of north-easterly and south-easterly winds. The summer winds represent the southern sector of the Inter-Tropical Convergence Zone while the winter winds are associated with the two seasonal anticyclonic systems that develop over the eastern part of the Sahara desert and south-western part of the Arabian Peninsula.

Within these general wind movements and systems, the coastal plain is subjected to a daily wind reversal brought about by the occurrence of land and sea breezes which are produced by the local difference in the atmospheric pressure over the sea and the nearby land-mass. The sea breeze over the Red Sea coast usually approaches from the north-east during the winter season and from

the north-east to the east during summer. These sea breezes are generally much stronger than the land breezes and their effect is confined largely to moderating the daily temperature and raising the humidity levels.

Regarding the upper winds over the Red Sea region, and if we take Port Sudan as a representative, we find that during the winter season, the lower part of the atmosphere up to about 7000 feet above the mean sea level, is dominated by upper winds with a strong easterly component. Above the 7000 feet level, however, the upper winds have a clear westerly component since they blow mainly from the west or the south-west. As the summer approaches all the upper winds become westerly though ranging between south west, west and north-west. The transitional periods between the summer and the winter season are largely dominated by upper easterlies that tend to blow from the north-east via east to south-east.

Visibility is occasionally reduced over the Red Sea Region. This may be attributed to the passage of a cold front over the region. As indicated above, such cold fronts move from west to east across the Sahara desert and the active winds behind them are capable of picking up and transporting large amounts of dust. The reduction in

visibility due to this activity may continue for several days. However, since these fronts are winter phenomena, their effect is necessarily confined to the winter season.

The summer season has its own mechanism for causing dust storms and thus reducing the visibility in the lower parts of the atmosphere. This usually occurs in association with the activities of the Inter -Tropical Convergence Zone (I.T.C.Z.) and thus it is likely to take place over the areas that lie south of the surface position of the I.T.C.Z. and so they may be expected in the Red Sea Region during the months of July and August. Such sand storms normally occur as a result of heavy downpours that raise the atmospheric pressure and also lead to massive air displacements which combine to activate the surface winds. Thus the winds start rushing northward, transporting enormous amounts of sands leading to a reduction in the visibility on the ground surface up to an appreciable depth of the troposphere. However, such sand storms are usually short-lived and may continue for a few hours rather than days. It should be mentioned here that the negative effects of these sand storms are largely felt within the southern part of the region, especially in the vicinity of Tokar where the presence of a wind gap

in the Red Sea hills allows these storms to carry their sand load to the waterline of the Red Sea. Further north, however, the hills act as an effective physical barrier and thus only the very fine dust may be carried eastward over the hills.

Another possible mechanism for producing dust storms over the Red Sea Region is associated with the local instability in the atmosphere that might produce local cumulonimbus cloud formations. Such vertically developing clouds produce very strong upward and downward motions that are capable of agitating the ground surface and carrying away a large amount of loose sand particles. These sands may be transported several hundred kilometers ahead of the area where the cumulonimbus clouds are developing. So, as a result of the thermal nature of these clouds the frequency of the resultant dust storms should necessarily drop during winter and also as the rainy season advances because these storms lose their dust source as the soil becomes wet and compact.

4- Rainfall

The location of the Red Sea Region as well as its characteristic physical setting that has been outlined above combine to give this region a unique precipitation regime that makes it distinctly different from the rest of the country. The exposure of the coastal plain to the prevailing north-easterly winds allows it to receive varying amounts of rainfall throughout the year but with a distinct winter maxima. Such a winter maxima is never experienced anywhere else in the Sudan.

Also the fact that the summit stations on the Red Sea hills are accessible to the winter rain-producing winds approaching from the sea as well as to the summer rain-producing winds approaching from the south-west behind the Inter Tropical Convergence Zone, this fact enables the summit stations, such as Erkowit, to enjoy a winter as well as a summer rainfall maxima. This double maxima that is produced by two different mechanisms during two distinctly different seasons is another unique feature of the Red Sea Region.

Beside these, the region is characterized by an ever-changing position of the rain shadow. The accessibility of the Red Sea hills to

the winter winds approaching from over the Sea makes the rain shadow coincides with the western slopes of these hills during the winter season. However, during the summer season, the rain shadow tends to occupy the eastern slopes of these same hills since during this time of the year the rain-producing winds approach from the south-west, thus allowing the winter rain shadow slopes to start acting as lee-ward slopes and the winter lee-ward slopes to start suffering from the negative rain shadow effects. So the rain shadow changes position as the season changes and this gives the Red Sea Region another unique characteristic that also distinguishes it from the rest of the country.

Connected with this latter factor, is the fact that the stations that lie west of the hills such as Haya and Derudeib, experience their maximum rainfall during the summer while the stations that lie east of the hills, such as Port Sudan and Tokar, receive their maximum rainfall during the winter season. So two contrasting rainfall regimes exist within relatively short distances thus giving the Red Sea Region a fourth unique climatic characteristic.

The water vapour needed for the precipitation process within the Red Sea Region is derived mainly from the nearby Red Sea. This

narrow Sea forms the constant source for water vapour but its limited extent enables it to yield very limited amount of water vapour. The inland transportation of the vapour is provided by the on-shore winds which intensify during the winter season but avail themselves throughout the year. This source is supplemented during the summer season by water vapour originated over the Guinean Gulf and trans-ported inland by the south-westerly monsoons.

The predominant uplifting mechanism in the region is orographically dictated by the nature and location of the Red Sea hills. The narrowness of the coastal plain enables all on-shore winds to reach the hills and thus to be subjected to orographical uplifting. Also the lack of wind gaps, except near Tokar, forces the approaching south westerlies to ride up the western slopes and thus to be subjected to effective orographical uplifting.

On the other hand, the possibility of thermal convection cannot be ignored completely, especially during the summer season. It could lead to local instability that may provide an effective uplifting mechanism.

The mean annual rainfall is generally low with the highest values largely confined to the summit stations such as Erkowit (148

mm). Unlike the case over the rest of the country, the annual isohyets here do not show a predominant correlation with the latitudinal position since the altitudinal factor, the proximity to the sea and the deflective effect of the Ethiopian plateau, are more prominent. Consequently, the isohyets here tend to follow a longitudinal or cellular pattern rather than the general latitudinal pattern that characterizes the rest of the country. In real terms, the mean annual rainfall ranges between a minimum of less than 25 mm in the extreme north and a maximum of around 250 mm over the hilly stations, but the nature of the region does not allow a generalization on the trend of the distribution of the annual rainfall. If the local distribution is considered, we may recognize a negative correlation between the mean annual rainfall and the latitudes over some parts of the region, while over other parts a positive correlation may exist between the mean annual rainfall and both the altitude and the distance from the sea. Over yet other parts of the region the correlation between the mean annual rainfall and the distance from the south-western border is more prominent and it is always negative. This latter correlation reflects the fact that the rain-producing winds approaching from the south-west, i.e. the

monsoonal winds, tend to lose their moisture content as they move inland in a north-easterly direction.

Regarding the monthly distribution of rainfall over the region, it is possible to consider April, May and June as dry months since less than 5% of the mean annual rainfall is received during any of these three months. However, while none of these months could be considered as completely dry for the entire region, all of them tend to be relatively wetter over the hilly area rather than over the coastal plain.

July and August are much wetter months especially over the hills where around 25% of the mean annual rainfall may be received during these two months. An exception to this is found over the extreme northern part of the coast where hardly any rain occurs during this time of the year. It is only natural that most of the July and August rains fall on the summit stations as well as on the western slopes of the Red Sea hills. It is here that the rain-producing south-westerly monsoons are more effective.

The month of September witnesses a sudden drop in rainfall amounts over the entire region since it usually witnesses the sudden and quick retreat of the I.T.C.Z. and its related south-westerly moist

winds. The conditions improve slightly during October which witnesses the occurrence of some light rains especially over the coast-land. However, a definite rainfall maxima occurs during November over most of the region especially over the coastland and the nearby eastern slopes and summit stations. In the extreme north, the coastal station, Halaib, receives more than 80% of its mean annual rainfall during November while less than 20% of the annual rains are received in the extreme southern part of the coastland during the same month. In between these two extremes, the rest of the coastland receives a monthly amount that ranges between 20% and 80% of their annual values.

The southern part of the coastland becomes wetter during December while the northern part becomes very dry. This may suggest a southward march of a narrow rainy belt associated with a gradual southward intensification of the on-shore winds blowing from the Sea and thus transporting an increasing amount of water vapour. The same trend is emphasized during December, January and February but with a continuous overall drop in the rainfall amounts. The month of February, in particular, witnesses a major drop in the rain-fall amounts over the entire region and even the

wettest part, i.e. the extreme southern part of the coastland does not receive more than 10% of its mean annual rainfall during this month. The next month, i.e. March, is usually the driest month for the region as a whole and although it is not a completely dry month, yet nowhere does the March value rises above the 2% level if expressed as a percentage of the mean annual rainfall.

A point to be noted here is that while the coastal station, Halaib, receives 80% of its annual rains during a single month, i.e. November, some of the summit stations tend to receive the bulk of their monthly values at two widely separated periods, namely August and January. In fact Erkowit, a representative of the summit stations, receives its highest monthly values, i.e. about 40% of its annual rains, during these two latter months and so it enjoys a summer as well as a winter maxima.

In spite of the complexity of the monthly distribution of the rainfall over the Red Sea Region, yet one may safely suggest the period November to January inclusive, as representative of what may be called the general rainy season of the Red Sea Region. These three months tend to experience 70 - 90% of the mean annual rainfall

over the entire region and hence they logically qualify for the above suggestion.

As anywhere else in the tropical region, the mean annual and monthly rainfall values show great variability and thus their actual values tend to fluctuate around these means. One possible way for measuring the degree of variability is the determination of the coefficients of variation which represents the expression of the standard deviation of the mean values as a percentage of these means. In this respect the mean annual coefficients of variation over the Red Sea Region tend to range between a minimum of around 50% over the southern part of the region, and a maximum of more, than 200% over the extreme northern part. However, the monthly coefficients of variation tend to range between 25% and 150% and they also increase in a general northward direction but with obvious interruptions dictated by the physical setting and the nature of the region.

These variability values are very high and thus they reflect a high degree of unreliability on both the annual and the monthly scales. Consequently, if rain cultivation is to be practiced in the region, that will necessarily involve a very big risk since several

years may pass without providing the farmer with the minimum amount of rainfall needed for raising the grain crops. If we take the generally accepted views on the risks involved in practicing rain cultivation, then the probability of the occurrence of more than two successive dry years with less than 100 mm of rainfall is quite common throughout the Red Sea Region and thus practicing rain cultivation is a real risk throughout the entire region for the very simple reason that rains here are both variable and unreliable.

5- Water Balance

Another important climatic aspect is that of the water balance over the Red Sea Region. In its simplest context, the water balance refers, to the relationship between the amount of water available in the form of rainfall and the amount of water lost from environment as a result of the combined effort of the processes of evaporation, transpiration and run-off. Of these latter processes, both evaporation and transpiration are difficult to measure precisely. This forced climatologists to seek some theoretical means for computing, or rather estimating, the amount of water lost. The most famous attempts in this connection are those of Penman and Thornthwaite which were both published in 1948. Penman's system seems to be very logical since it tends to in-corporate all the elements that may play a part in the physical processes of evaporation and transpiration. However, the complexity of Penman's equation and the difficulty of obtaining the required variables from a reasonable number of stations, limit its application in many parts of the world, including the Sudan.

The other system available for estimating the water-loss from the environment, i.e. the Thornthwaite's system, is simpler and easy to apply since the variables required are generally available. Beside this, the Thornthwaite's system tended to introduce a new concept in the estimation of the water-loss by emphasizing the significance of the maximum amount of water that is likely to be lost from the environment under conditions of unlimited water supply. According to this concept, the water balance should reflect the relation between the rainfall and the amount of water that is likely to be lost by evaporation and transpiration under the assumption that these latter processes are not hindered by a shortage in the water supply. So here the emphasis is on the theoretical rather than the actual values of evaporation and transpiration. In other words, the emphasis is on the so-called potential Evapo-transpiration and it is determined by a mathematical formula suggested by Thornthwaite in 1948.

Several attempts were made to apply the Thornthwaite's system to the Sudan. These include for example the works of Satakopan (1965), Oliver (1965 & 1969), El Seed (1968), Fayed (1965) and Awadalla (1977). While Awadalla (1988) is experimenting on the possibility of combining Penman's and

Thornthwaite's systems in a single formula, the pioneering work of Satakopan (1965) remains to be reasonably valid for the whole of the Sudan except perhaps for some limited areas in the central part of the country where the generalization provided by the Thornthwaite's system does not reflect some of the known local differences.

When applying the Thornthwaite's system to the Red Sea Region, it indicates that the entire region suffers from acute water deficit on both the annual and the monthly scales. The highest values of the annual water deficit are found on the areas that lie to the west of the Red Sea hills such as Haya and Derudeib whose mean annual rainfalls are 76 mm and 136 mm respectively, while their annual potential-evapo-transpiration (P.E.T.) are 1723 mm and 1829 mm. This makes Haya to suffer a deficit of 1647 mm annually while Derudeib suffers a deficit of 1693 mm annually.

On the eastern side of the hills, i.e. over the coastplain, conditions are as bad as they are on the west. The coastplain may be represented by Port Sudan and Tokar whose mean annual rainfalls are 107 mm and 90 mm respectively. Port Sudan has an annual P.E.T. value of 1727 mm, thus suffering an annual water deficit of

1620 mm. On the other hand Tokar suffers an annual water deficit value of 1714 mm since its annual P.E.T. is 1804 mm.

The conditions on the hills are slightly better but even there the water supply is much lower than that needed for the processes of evaporation and transpiration. The annual water deficit at the summit station of Erkowit is 891 mm as its mean annual rainfall is 248 mm while its annual P.E.T. is 1139 mm.

Regarding the monthly conditions, we may select November and March to represent the wet and the dry months respectively. As indicated earlier, November is the rainiest month over most of the Red Sea Region, while March is the driest month over the entire region.

During November, the western stations, Haya and Derudeib, have mean monthly rainfall values of 1 mm and 7 mm respectively. With P.E.T. values of 127 mm and 139 mm, Haya has a water deficit of 126 mm during November while Derudeib's deficit during the same month is 132 mm.

On the coastal plain, conditions are slightly better but again a large water deficit dominates. Port Sudan, for example, has a mean monthly rainfall of 41 mm during November while its P.E.T. during

the same month is 134 mm, making a monthly water deficit of 93 mm. A similar trend is found over the other coastplain stations, i.e. Tokar, whose November values of rainfall, P.E.T. and water deficit are 23 mm, 140 mm and 117 mm respectively.

The hilly station, Erkowit, enjoys a mean November rainfall of 23 mm, but with a P.E.T. of 62 mm during the same month it attains a water deficit of 39 mm which although lower than anywhere else in the region yet still confirms the general extreme aridity of the region as a whole.

This trend is further confirmed during the driest part of the year which is here represented by March. On the western side of the hills, general dryness prevails and Haya and Derudeib hardly receive any rains during this month so their mean rainfall values are at the zero level. However, the March P.E.T. values for Haya and Derudeib are 119 mm and 150 mm respectively, and thus these same figures represent the March water deficit over the stations under consideration.

Over the coastal plain, the March conditions are not as completely dry as on the west of the hills, but there the mean rainfall values hardly rise above the 1 mm level for both Port Sudan and

Tokar while the P.E.T. at these same stations are 88 mm and 109 mm respectively. This makes Port Sudan suffer a monthly water deficit of 87 mm while the water deficit at Tokar rises to 108 mm. During the same month, Erkowit is slightly wetter with a mean monthly rainfall value of 5 mm, but it suffers from a water deficit of 43 mm since the March P.E.T. value for Erkowit is 48 mm.

So on the basis of the Thornthwaite's 1948 system of climatic classification, the entire Red Sea Region lies within the Arid climatic belt with annual Moisture Indices that range between (- 40) and (- 60). The actual annual Moisture Indices for our representative stations are:

Haya (- 57.5); Derudeib (- 55.5); Port Sudan (- 56.3); Tokar (- 57.0); Erkowit (- 46.9).

This confirms the previous observation that although aridity dominates the entire region, yet the conditions over the hilly part are slightly better. This is further confirmed if the classical Koppen's climatic classification is applied, but then the hilly part may be singled out as having a lesser arid type of climate while the rest of the region has a definite (BWh) climate. So, according to Koppen's system, the Red Sea Region is an entirely hot arid region but with

slight differences in the precipitation effectiveness that might be relatively higher at the summit stations where the temperatures are generally lower, thus leading to slightly lower evaporation values. In connection with the question of precipitation effectiveness, it may be worth mentioning here that a preliminary investigation over the Sudan (El Tom, 1977) has revealed noticeable diurnal variations in the Red Sea Region. Generally the southern part of the region tends to receive more than 50% of its rains during the night-time between 12 midnight and 6 a.m. In the central and northern parts, however, the morning period, 6 a.m. to 12 noon, seems to be the most favourable for rainfall occurrences. Within these general conditions the rains may fall any-time during the day over the coastal plain but a definite night minima is observed over that plain. This may be attributed to the dominance of the land breeze during the night time which seems to check the transportation of water vapour from over the Red Sea. This coincides with the fact that the land breeze triggers an eastward motion of air down the eastern slopes of the Red Sea hills, a motion that contradicts with that needed for starting condensation and orographic precipitation. So the degree of precipitation effectiveness could be affected by the time of rainfall

occurrence since the night rains are expected to be more effective than the day rains due to the fact that evaporation and transpiration reach their lowest levels during the night time, thus allowing the environment to utilize most of the waters of the incident rain.

So the Red Sea Region is a unique area of its physical setting and its climatic characteristics. It differs considerably from the rest of the country and at the same time it shows great internal differences that are dictated by the physical setting and the climatic controls that have been outlined above.

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Table (1)

Selected climatic data for representative stations in the Red Sea Region.

STATION NAME	LAT (N)	LONG (°E)	ALT (M)	TEMP. (°C)			RAINFALL (mm)		
				YEAR	JAN	JUNE	YEAR	MAR.	NOV.
DERUDEIB	17°33'	36°06'	509	29.1	24.3	33.1	136	0	7
ERKOWIT	18°46'	37°06'	1095	22.0	15.4	27.7	248	5	23
HAYA	18°20'	36°22'	643	28.2	23.1	32.7	76	0	1
PORT SUDAN	19°35'	37°13'	08	28.7	23.7	32.3	107	1	41
TOKAR	18°26'	37°44'	20	29.7	24.3	33.9	90	1	23

Sources:

Dept. of Meteorology: Climatological Normals

Bhalotra: Meteorology of the Sudan

Satakopan: Water balances in the Sudan.

Table (2)

Selected climatic data for representative stations in the Red Sea Region.

STATION NAME	P.E.T.			WATER DEFICIT (mm)			MOISTURE INDEX
	YEAR	MAR.	NOV.	YEAR	MAR.	NOV.	
DERUDEIB	1829	150	139	1693	150	132	-55.5
ERKOWIT	1139	48	62	891	43	39	-46.9
HAYA	1723	119	127	1647	119	126	-57.5
PORT SUDAN	1727	88	134	1620	87	93	-56.3
TOKAR	1804	109	140	1714	108	117	-57.0

Sources:

Dept. of Meteorology: Climatological Normals

Bhalotra: Meteorology of the Sudan

Satakopan: Water balances in the Sudan.



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