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Publisher: Routledge

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Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK

Scottish Geographical Magazine

Publication details, including instructions for authors and subscription information:

<http://www.tandfonline.com/loi/rsgj19>

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John Murray

Published online: 30 Jan 2008.

To cite this article: John Murray (1887) On the total annual rainfall on the land of the globe, and the relation of rainfall to the annual discharge of rivers, *Scottish Geographical Magazine*, 3:2, 65-77, DOI: [10.1080/14702548708554511](https://doi.org/10.1080/14702548708554511)

To link to this article: <http://dx.doi.org/10.1080/14702548708554511>

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THE SCOTTISH GEOGRAPHICAL MAGAZINE.

ON THE TOTAL ANNUAL RAINFALL ON THE LAND OF
THE GLOBE, AND THE RELATION OF RAINFALL TO
THE ANNUAL DISCHARGE OF RIVERS.

BY JOHN MURRAY.

(Abstract of Paper read before the Royal Society of Edinburgh, 17th January 1887.)

It is well known that the earth is surrounded by three atmospheres, one of oxygen, one of nitrogen, and one of water vapour. In the case of the oxygen and nitrogen, a complete mixture takes place throughout the whole atmospheric envelope according to the known laws of gaseous diffusion. A similar complete mixture is never attained in the case of aqueous vapour; this arises from the fact that the equilibrium of the water-vapour atmosphere is continually being disturbed by the ceaseless processes of condensation and evaporation, the amount of which varies with every change of temperature and pressure. Vapour is ever passing into the air at all temperatures and pressures from the surface of the sea and land, and is as continuously being withdrawn again from the air in the form of rain, snow, hail, and dew-drops. There is, in reality, a continuous aqueous aerial circulation, constant currents of water passing, as it were, from ocean to continent, and from one portion of the surface of the land and sea to another.

This circulation plays such an important part in many terrestrial and oceanic phenomena that it is evidently a matter of considerable importance to be able to estimate, even approximately, its absolute amount as a whole, and its relative amount on different regions of the earth's surface, as well as to estimate what portion of the rain that falls on the land finds its way back again to the ocean by means of rivers. It is admitted that our knowledge of the rainfall on the surface of the land is very incom-

plete, and our knowledge of the amount of water discharged by the principal rivers of the globe cannot be said to be in a more satisfactory state than our knowledge of the rainfall. Still, with the data at present available, the estimates above referred to have been made, and the results are presented in this communication, so far as the investigation has up to this time proceeded.

Professor Loomis of Yale College has for many years collected data concerning the annual rainfall in the different regions of the world, and has portrayed these on a map of the world by means of lines passing through places of equal rainfall. Taking the data furnished by Professor Loomis' map as a foundation, I have transferred these to maps of the world on an equal surface projection.¹ The maps which accompany this paper are reduced by Mr. Bartholomew from those used in the investigation. The maps were revised for me by Mr. Alexander Buchan, who has added the most recent information available, and has advised me as to the mean annual rainfall which should be adopted in estimating the rainfall in each area.

The planimeter was used in defining the extent of the areas where the rainfall was under 10, between 10 and 25, 25 and 50, 50 and 75, and over 75 inches annually, and from these data the total annual rainfall on the land has been calculated.

In like manner there has been estimated the total amount of rain falling on each of the continents and principal islands, on each ten degrees of latitude north and south, on each of the drainage areas of the oceans and inland drainage areas, and on the catchment basins of many of the principal rivers. The results are set forth in the accompanying tables.

From an inspection of these tables it will be seen that the total annual rainfall of the globe is estimated at 29,350 cubic miles, which is the mean of several measurements. Of this amount 2,243 cubic miles of rain fall on the inland drainage areas of the globe, such as the Caspian, Sahara, and similar areas in all the continents. These inland drainage areas occupy 11,486,350 square miles, and as no water is discharged from them into the ocean it follows that all the water which falls as rain must be again returned to the atmosphere by evaporation. Should the water accumulate in these areas into lakes, and these lakes show a slight annual increase in size, then the rainfall must be regarded as greater than the evaporation; but when, as in the case of the Great Salt Lake of North America, the size of the lake slowly diminishes, then the evaporation over the basin must be greater than the rainfall.

The rainless regions of the earth correspond in locality very closely with these inland drainage areas, the rainless regions being defined as those in which the annual rainfall is less than 10 inches. The area of such regions is 12,200,000 square miles. Again, the inland drainage areas, the rainless regions, and the great desert regions, largely coincide,

¹ See *Scottish Geographical Magazine* for September 1886, p. 549.

or overlap each other, and are situated in two belts around the world, one in the northern hemisphere, approximately between the latitudes of 30° and 40° , and one in the southern hemisphere, approximately between the latitudes of 20° and 30° , the configuration of the land determining to a large extent their position. In the northern belt there are the Desert of Gobi, the Aral and Caspian basins, the Dead Sea area, the deserts of Arabia, the Sahara in North Africa, and the Great Salt Lake and Alkali deserts of the Rocky Mountains. In the southern belt there are the arid region of the interior of Australia, the Kalahari desert of Africa, and the Atacama desert of South America.

The area of the inland drainage areas is a little over one-fifth of the total land of the globe. Were evaporation to take place over the whole land at the same rate as from these inland areas, it would be equal to about one-third of the total rainfall; but it is evident that the evaporation from inland areas is much less than it would be were more water present in them. The Mediterranean and Red Sea, for instance, are situated in one of the driest of these regions, and the evaporation from their surface must be enormous. The discharge of rivers into the Mediterranean and Black Seas is estimated at 226 cubic miles, and the area of their combined surfaces at 1,053,000 square miles. Not only is all the 226 cubic miles of water evaporated from the surface of these seas, but a very large quantity in addition, for, as is well known, the water of the Mediterranean is saltier than that of the Atlantic with which it communicates. Fresher Atlantic water continually flows in through the Straits of Gibraltar, while saltier dense water flows out as an under-current from the Mediterranean to the Atlantic. Saltier water also flows as an under-current into the Black Sea, while fresher water flows from the Black Sea into the Mediterranean at the surface.

The primary cause of the rainless, desert, and inland drainage areas is to be traced to the fact that they are situated in those regions of the earth's surface where the winds blow from colder to warmer latitudes, and from off land and not from off the ocean. An examination of the accompanying maps in connection with one showing prevailing winds will make this at once apparent.

As none of the rain falling on inland drainage areas ever reaches the sea by means of rivers, these areas may be deducted from the total land of the globe, which leaves 44,211,050 square miles of land which drain into the ocean. Of this 44,211,050 square miles, 26,400,000, or considerably over one-half of it, drain into the Atlantic Ocean and the basins which open into it, as the Mediterranean, Baltic, and Arctic Ocean; and of the 27,110 cubic miles of rain which fall on the land draining into the oceans, 15,788 cubic miles, or more than one-half of the total rainfall of the globe, falls on the Atlantic drainage area. The amount of rain falling annually on the Pacific and Indian Ocean drainage areas is respectively 5,007 cubic miles, and 4,379 cubic miles, or in each case less than one-third of the rain falling on the Atlantic Ocean drainage area.

The rain or snow falling on the Antarctic continent is estimated at 1,688 cubic miles. It will thus be seen that the Atlantic is as remarkable for the amount of rain falling on the land draining into it, as for the extent of that land itself, when compared with the land draining into the other oceans. This fact, as will be pointed out in another paper, has a very important influence on the nature of the deposits now forming in the Atlantic, as compared with those of the Pacific.

In the table showing the rainfall according to latitude, it will be noticed that the greatest amount of rain falls on the land within the tropical regions, and that the amount per square mile diminishes on the whole, but somewhat irregularly, towards the poles. It will be noted that there is a slight diminution between 20° and 30° South, and 30° and 40° North, which is evidently due to the great extent of the rainless regions in those latitudes. South of these latitudes in the southern hemisphere, there is a very considerable increase of the amount of rain per square mile, which is to be accounted for by the relatively small proportion of land to sea as compared with the northern hemisphere, where there is a decrease per square mile as the North Pole is approached. The total amount of rain falling on the land also diminishes towards the poles, with the exception of that falling on the Antarctic continent. The rainfall on the land surrounding the South Pole has been estimated as being on the average 30 inches per annum. It is unlikely that this is too high, when we remember that the winds blow into it cyclonically from the surrounding Southern Ocean, carrying with them the moisture evaporated from lower latitudes, and that on the borders of this land there is at some seasons almost constant precipitation.

The area of the land between 30° North and 30° South is 25,628,550 square miles, and the rain falling on this land is estimated at 18,891 cubic miles, or nearly two-thirds of the total rainfall on the land of the globe. The land between 30° North and the North Pole is estimated at 24,114,800 square miles, and the rainfall on it at 7,580 cubic miles. The land between 30° South and the South Pole is estimated at 5,521,300 square miles, and the rainfall on it at 2,639. It will thus be noticed that of the rain which falls outside of the 30° North and South, a larger quantity falls in the southern in proportion to the quantity of land than in the northern hemisphere, which was to have been expected from the greater extent of water surfaces in this part of the globe.

A study and comparison of the appended tables reveal many other interesting facts of a similar kind, and many relations might be pointed out between the nature of the regions, their animal and vegetable productions and populations, in which there is a small or a large annual rainfall, did such considerations come within the scope of the present paper.

Turning now to the consideration of what becomes of the water which falls upon the land in the form of rain, snow, hail, and dew, it is at once evident that by far the larger portion of it, after remaining for a

longer or shorter period on the land, is evaporated and carried away again by the atmosphere. That portion of the rainfall which is used up by plants and animals may be regarded as a constant quantity, for the amount locked up in the bodies of one set of organisms in the course of a year may be regarded as equivalent to what is returned by the death and decay of another set during the same period. A very large quantity of water has doubtless been stored up in the deeper parts of the earth's crust, and much of it permanently fixed through the hydration of minerals; although the total amount of rainfall which has disappeared in this way must be very large, and be constantly increasing, still its annual amount must be relatively very small, and may be neglected in the present discussion. The water which finds its way to the ocean by underground channels is also probably small in annual amount, and for our present purposes may be left out of account.

The difference between the total rainfall on the land and the total amount of water discharged by rivers into the ocean may then be regarded as that portion of the rainfall which is evaporated from the land in the course of the year; and the total amount of water discharged by rivers annually is a measure of the excess of evaporation over precipitation on the oceans and seas, as well as a measure of the excess of precipitation over evaporation from land surfaces.

In only a relatively few cases have the discharges of rivers been estimated with great care: in the majority of cases there is considerable divergence in the statements by different authorities as to the annual discharge of the same rivers. In the accompanying table (VI.) there are given the areas of the catchment basins, a mean of the annual discharges, and the mean ratio of the discharges to the annual rainfall on the basins of thirty-three rivers, concerning which we appear to have the most trustworthy information.

The proportion of the rainfall on the catchment basin of a river to the amount of water discharged at its mouth varies according to the geographical position of the river. In the case of European rivers, between one-third and one-fourth of the rainfall reaches the sea. One-third of the rain which falls on the British Isles is believed to reach the sea by rivers. The Mississippi has been estimated with great care, and it is found that one-fourth of the rainfall is discharged into the Caribbean Sea. The St. Francis and Yazoo, tributaries of the Mississippi, which flow through a wooded country, deliver nearly all the rainfall at their mouths. It would appear that fully one-half of the rain which falls on the basin of the Yukon in Alaska finds its way to the sea. Within the tropics a very much larger proportion of the rainfall would appear to be evaporated. The Nile, the lower part of which flows through an exceptionally dry and sandy region, delivers only about $\frac{1}{37}$ of the rainfall on its catchment basin into the Mediterranean; but the usual discharge of tropical or sub-tropical rivers appears on an average to be about one-fifth of the rainfall on the river's basin.

The thirty-three rivers given in Table VI. drain 13,272,000 square miles of land, and discharge into the ocean 2,182 cubic miles of water. If water were discharged from the whole land of the globe at the same rate, the amount per annum would be 9,159 cubic miles. This is, however, much too high a number for the total discharge; to make a fair comparison it is necessary to deduct from the land of the globe all the inland drainage areas, for we have seen that no water drains from them into the sea. When the inland drainage areas (11,486,350 square miles) are deducted from the total land of the globe (55,697,400 square miles) there remain, as we have seen, 44,211,050 square miles. If the discharge of water from this land were at the same rate as from that drained by the thirty-three rivers, the total discharge into the ocean would be 7,270 cubic miles per annum. Even this number is too high, for the thirty-three rivers represent chiefly regions where the rainfall is very considerable, and poorly represent regions of the earth's surface (outside the inland drainage areas) where the rainfall is under 10 inches annually, nearly all of which may be regarded as evaporated. Making deductions suggested by these considerations, there remain 39,697,400 square miles as the area of the earth's surface from which water drains into the sea; and the total discharge from this land is calculated, in the same way as above, to be 6,528 cubic miles annually, or to the total rainfall on the land of the globe as 1 to 4.496.

There is, however, an advantage in considering the rainfall in connection with the discharge in different regions. With this view if we take the discharge of fourteen¹ rivers (in Table VI.) whose basins are for the most part situated between the latitudes of 30° N. and 30° S., we find that they drain 9,117,000 square miles, and discharge into the ocean 1,694 cubic miles. At this rate the whole of the land between 30° N. and 30° S. (25,628,550 square miles) would discharge 4,763 cubic miles, but deducting the inland drainage areas situated in these regions the total discharge into the sea would be 3,740 cubic miles, which is to the rainfall between 30° N. and 30° S. (18,891 cubic miles) as 1 to 5.051.

If now we take the nineteen rivers (in Table VI.) whose basins lie mostly or wholly outside of 30° N. and 30° S., we find that they drain 4,155,000 square miles, and discharge into the sea 488 cubic miles. At the same rate all the land north and south of the 30th parallels (29,643,100 square miles) would give 3,197 cubic miles. Deducting the inland drainage areas in these regions, the discharge would then be 2,779 cubic miles, or to the rainfall in the same regions (10,219) as 1 to 3.677. The total discharge is by this calculation 6,520 cubic miles; by the previous calculation it was 6,528. The mean of these two numbers, or 6,524 cubic miles, may be taken as approximately the amount of water which is discharged from the land by rivers in the course of a year.

¹ Congo, Nile, Orange, Yang-tse-kiang, Irawadi, Ganges, Indus, Godavery, Kistna, Amazonas, La Plata, Orinoco, San Francisco, and Magdalena.

And of this amount 3,947 cubic miles are poured into the Atlantic and its partially enclosed seas. This total discharge is to the total rainfall on the land of the globe as 1 to 4·499.

In a subsequent paper the amount of matter in solution and suspension carried from the land to the sea by rivers in the course of one year will be discussed in some detail. At present it may be stated that the analyses of nineteen rivers have been taken as representing on an average the composition of river water. It will be seen by reference to Table VII. that according to these analyses each cubic mile of river water which reaches the sea carries with it 762,587 tons of dissolved matter.

The amount of water draining from the land in the course of a year is, as we have seen, 6,524 cubic miles. At the above rate this would give for matter in solution carried by the rivers from the land in one year 4,974,967,588 tons.

For the purposes of comparison, Table VIII. is given to show the matter in solution in a cubic mile of sea water.

I have to acknowledge the assistance of Mr. James Chumley and Mr. John Gunn in making the calculations in this paper.

TABLE I.—Showing the RAINFALL on the land of the Globe, arranged in continents and islands, with the estimated total amount in cubic feet and miles.¹

AFRICA.		
Inches.	Sq. Eng. Miles.	Cubic Feet.
Under 10,	3,221,000	37,414,583,300,000
10-25,	2,450,600	102,476,730,000,000
25-50,	2,740,900	241,967,530,000,000
50-75,	2,562,850	375,090,082,500,000
Over 75 { [mean, 100], .	201,300	46,767,666,600,000
{ [„ 110], .	209,050	53,422,370,830,000
	11,385,700	857,138,963,230,000
MADAGASCAR.		
Inches.	Sq. Eng. Miles.	Cubic Feet.
10-25,	77,400	3,237,765,000,000
25-50,	85,200	7,518,838,300,000
50-75,	77,400	11,332,177,500,000
	240,000	22,088,780,800,000
EUROPE.		
Inches.	Sq. Eng. Miles.	Cubic Feet.
Under 10,	139,350	1,615,181,250,000
10-25,	2,547,350	106,524,600,000,000
25-50,	967,850	85,441,258,300,000
50-75 { [mean, 60], .	50,350	7,015,080,000,000
{ [„ 63], .	81,300	11,898,705,000,000
	3,786,200	212,494,824,550,000

¹ In these tables, the mean taken in the calculations where the rainfall was under 10 inches was 5 inches, 10 to 25 was 18 inches, 25 to 50 was 38 inches, 50 to 75 was 63 inches. When other means were taken, these are stated in the table within brackets.

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ASIA.			
Inches.	Sq. Eng. Miles.	Cubic Feet.	
Under 10,	5,892,250	68,442,830,000,000	
10-25,	6,651,000	278,124,900,000,000	
25-50,	2,357,650	208,138,600,000,000	
50-75,	890,400	130,319,962,500,000	
Over 75 {	[mean, 85],	46,450	9,152,530,830,000
	[„ 90],	92,900	19,426,500,000,000
	[„ 100],	7,750	1,798,591,600,000
	[„ 120],	58,100	16,188,750,000,000
	[„ 170],	232,300	91,525,308,300,000
	16,228,800	823,117,973,230,000	
JAVA.			
Inches.	Sq. Eng. Miles.	Cubic Feet.	
Over 75 [mean, 110],	54,200	13,850,466,600,000	
SUMATRA.			
Inches.	Sq. Eng. Miles.	Cubic Feet.	
Over 75 [mean, 130],	185,800	56,119,808,300,000	
CELEBES.			
Inches.	Sq. Eng. Miles.	Cubic Feet.	
Over 75 [mean, 120],	77,400	21,585,100,000,000	
BORNEO.			
Inches.	Sq. Eng. Miles.	Cubic Feet.	
Over 75 [mean, 100],	290,350	67,453,166,000,000	
FLORES, Etc.			
Inches.	Sq. Eng. Miles.	Cubic Feet.	
50-75 [mean, 54],	30,950	3,885,217,200,000	
PHILIPPINES.			
Inches.	Sq. Eng. Miles.	Cubic Feet.	
Over 75 [mean, 90],	123,900	25,901,445,000,000	
FORMOSA.			
Inches.	Sq. Eng. Miles.	Cubic Feet.	
Over 75 [mean, 85],	15,500	3,057,811,250,000	
JAPAN.			
Inches.	Sq. Eng. Miles.	Cubic Feet.	
50-75,	96,800	14,165,261,250,000	
Over 75 [mean, 80],	46,450	8,634,000,000,000	
	143,250	22,799,261,250,000	
SAGHALIEN.			
Inches.	Sq. Eng. Miles.	Cubic Feet.	
10-25 [mean, 25],	38,700	2,257,664,166,000	

AUSTRALIA AND TASMANIA.

Inches.	Sq. Eng. Miles.	Cubic Feet.
Under 10, . . .	1,196,250	13,896,358,300,000
10-25, . . .	998,800	41,767,350,000,000
25-50, . . .	561,350	49,555,166,000,000
50-75 [mean, 65], . . .	247,800	37,413,203,750,000
	<hr/> 3,004,200	<hr/> 142,632,078,050,000

NEW ZEALAND.

Inches.	Sq. Eng. Miles.	Cubic Feet.
25-50 [mean, 36], . . .	19,350	1,618,819,500,000
50-75 [„ 60], . . .	77,450	10,792,550,000,000
	<hr/> 96,800	<hr/> 12,411,369,500,000

NEW GUINEA.

Inches.	Sq. Eng. Miles.	Cubic Feet.
Over 75 [mean, 120], . . .	340,700	94,974,600,000,000

NORTH AMERICA.

Inches.	Sq. Eng. Miles.	Cubic Feet.
Under 10, . . .	1,432,400	16,638,516,600,000
10-25, . . .	2,942,250	123,033,990,000,000
25-50, . . .	2,926,750	258,370,043,300,000
50-75 { [mean, 53], . . .	34,850	4,290,119,630,000
{ [„ 60], . . .	905,900	126,273,400,000,000
Over { [„ 85], . . .	92,900	18,347,250,000,000
{ [„ 90], . . .	69,700	14,569,875,000,000
	<hr/> 8,404,750	<hr/> 561,523,194,530,000

GREENLAND.

Inches.	Sq. Eng. Miles.	Cubic Feet.
10-25, . . .	735,550	30,757,845,000,000
25-50, . . .	77,450	6,835,281,600,000
	<hr/> 813,000	<hr/> 37,593,126,600,000

WEST INDIES.

Inches.	Sq. Eng. Miles.	Cubic Feet.
50-75, . . .	85,150	12,465,437,250,000

ICELAND.

Inches.	Sq. Eng. Miles.	Cubic Feet.
25-50, . . .	25,150	2,221,397,600,000
50-75, . . .	9,700	1,416,467,325,000
	<hr/> 34,850	<hr/> 3,637,864,925,000

SOUTH AMERICA.

Inches.	Sq. Eng. Miles.	Cubic Feet.
Under 10, . . .	333,050	3,868,537,500,000
{ 10-25 [mean, 25], . . .	483,900	28,105,416,600,000
{ 10-25, . . .	189,700	7,932,267,000,000
25-50, . . .	623,300	55,033,360,000,000
50-75, . . .	3,979,750	582,478,050,000,000
Over 75 { [mean, 100], . . .	185,800	43,169,083,300,000
{ [„ 120], . . .	1,122,700	312,986,300,000,000
{ [„ 130], . . .	135,500	40,922,580,830,000
	<hr/> 7,053,700	<hr/> 1,074,495,595,230,000

ANTARCTIC CONTINENT.

Inches. Sq. Eng. Miles. Cubic Feet.
25-50 [mean, 30], 3,565,550 248,497,500,000,000

SUMMARY.

Continent.	Area in Square Miles.	Rainfall in Cubic Feet.	Cubic Feet per Sq. Mile.	Total Rain in Cubic Miles.
Africa, . .	11,385,700	857,138,963,230,000	75,280,170	5,822·9
Madagascar, . .	240,000	22,088,780,800,000	92,037,500	150·1
Europe, . .	3,786,200	212,494,824,550,000	56,122,230	1,443·5
Asia, . .	16,228,800	823,117,973,230,000	50,719,080	5,591·8
Java, . .	54,200	13,850,466,600,000	255,535,000	94·1
Sumatra, . .	185,800	56,119,808,300,000	302,045,200	381·2
Celebes, . .	77,400	21,585,100,000,000	278,876,000	146·6
Borneo, . .	290,350	67,453,166,000,000	232,316,200	458·2
Flores, etc., . .	30,950	3,885,217,200,000	125,531,500	26·4
Philippines, . .	123,900	25,901,445,000,000	209,047,600	175·9
Formosa, . .	15,500	3,057,811,250,000	197,277,400	20·8
Japan, . .	143,250	22,799,261,250,000	159,155,300	154·9
Saghalien, . .	38,700	2,257,664,166,000	58,338,500	15·3
Australia, etc., . .	3,004,200	142,632,078,050,000	47,476,870	968·9
New Zealand, . .	96,800	12,411,369,500,000	128,212,800	84·3
New Guinea, . .	340,700	94,974,600,000,000	278,761,300	645·2
S. America, . .	7,053,700	1,074,495,595,230,000	152,331,400	7,299·6
N. America, . .	8,404,750	561,523,194,530,000	66,810,230	3,814·7
W. Indies, . .	85,150	12,465,437,250,000	146,388,700	84·7
Greenland, . .	813,000	37,593,126,600,000	46,239,860	255·4
Iceland, . .	34,850	3,637,864,925,000	104,387,400	24·7
Antarctic Cont. . .	3,565,550	248,497,500,000,000	69,695,700	1,688·2
Total, . .	55,999,450	4,319,981,247,661,000		29,347·4

TABLE II.—Showing the Amount of Land with a Rainfall of under 10 inches, from 10 to 25 inches, 25 to 50, 50 to 75, and over 75 inches, with the estimated total rainfall annually in cubic miles:—

Inches.	Area in Square Miles.	Rainfall in Cubic Feet.	Cubic Feet per Sq. Mile.	Total Rain in Cubic Miles.
Under 10	12,214,250	141,876,006,950,000	11,615,360	963·8
10-25	17,115,350	723,579,725,100,000	42,277,540	4,915·6
25-50	13,958,250	1,165,886,389,600,000	83,529,160	7,920·3
50-75	9,138,350	1,329,977,326,405,000	145,541,300	9,035·3
Over 75	3,588,750	959,853,204,440,000	267,464,550	6,520·7

TABLE III.—Showing Rainfall on land of the Globe, arranged according to Drainage Areas of the great Oceans and Inland Drainage Areas, with estimated total amount falling on each area annually in cubic miles :—

	Area in Square Miles.	Rainfall in Cubic Feet.	Cubic Feet per Sq. Mile.	Total Rain in Cubic Miles.
Atlantic, . . .	14,296,950	1,747,914,843,010,000	122,256,400	11,874·3
Mediterranean, &c.	2,969,350	235,232,989,130,000	79,220,700	1,598·0
Baltic, . . .	611,700	25,938,068,160,000	42,403,140	176·2
Arctic, . . .	8,660,250	314,981,821,300,000	36,371,000	2,139·8
Pacific, . . .	7,579,250	737,040,260,334,000	97,245,100	5,007·1
Indian, . . .	6,813,600	644,577,278,906,000	94,600,500	4,378·9
Antarctic, . . .	3,565,550	248,497,500,000,000	69,695,700	1,688·2
Inland areas, . .	11,486,350	329,988,431,000,000	28,729,760	2,241·8

TABLE IV.—Giving in detail the Rainfall on the various Inland Drainage Areas of the World, with the total amount on each in cubic miles :—

	Area in Square Miles.	Rainfall in Cubic Feet.	Cubic Feet per Sq. Mile.	Total Rain in Cubic Miles.
Sahara, . . .	3,449,400	107,303,672,766,000	31,106,860	728·9
Kalahari, . . .	61,950	2,122,520,830,000	34,261,500	14·4
Abyssinia, . . .	50,300	5,566,944,191,000	110,673,900	37·8
S. America, . . .	507,150	24,642,452,000,000	48,589,180	167·4
N. America, . . .	274,850	12,815,735,765,000	46,629,080	87·1
Eural-Asia, . . .	5,598,000	140,465,518,330,000	25,125,040	955·5
Australia, . . .	1,544,700	37,051,899,600,000	23,986,540	251·7

TABLE V.—Showing Amount of Land, annual Rainfall in cubic feet and cubic miles, and cubic feet per square mile, for each 10° of Latitude :—

Latitudes.	Area in Square Miles.	Rainfall in Cubic Feet.	Cubic Feet per Sq. Mile.	Total Rain in Cubic Miles.
80°—90° N.	85,150	2,625,992,830,000	30,839,685	17·8
70°—80° N.	1,211,800	39,099,401,750,000	32,265,220	265·6
60°—70° N.	5,067,650	172,135,024,166,000	33,966,770	1,177·5
50°—60° N.	5,578,600	278,789,202,127,000	49,974,910	1,893·9
40°—50° N.	6,298,750	325,773,402,376,000	51,720,200	2,213·1
30°—40° N.	5,872,850	296,230,537,993,000	50,441,010	2,012·4
20°—30° N.	5,892,250	363,010,621,876,000	61,608,560	2,466·1
10°—20° N.	4,537,250	394,354,254,321,000	86,914,840	2,679·0
0°—10° N.	3,879,100	697,061,826,883,000	179,696,350	4,735·5
0°—10° S.	4,064,950	699,776,286,345,000	172,151,800	4,753·9
10°—20° S.	3,670,100	411,798,546,467,000	112,204,000	2,797·5
20°—30° S.	3,584,900	214,790,710,656,000	59,915,210	1,459·2
30°—40° S.	1,502,050	95,663,938,508,000	63,691,070	649·9
40°—50° S.	383,250	36,922,903,223,000	96,341,800	250·8
50°—60° S.	77,450	7,378,860,083,000	95,273,090	50·1
60°—90° S.	3,565,550	248,497,500,000,000	90,604,400	1,688·2

TABLE VI.—Showing the Drainage Area, annual Rainfall, annual Discharge, and Ratio of Discharge to Rainfall, of 33 rivers in different parts of the world.

Position of Mouth of River.	River.	Drainage Area in Sq. Miles.	Annual Rainfall in Cubic Miles.	Mean Annual Discharge in Cubic Miles.	Mean Ratio.
50°—60° N.	Rhine, . . .	32,600	19·500	10·100	2·049
	Oder, . . .	51,100	14·700	2·500	5·803
	Niemen, . . .	36,450	10·355	3·783	2·737
40°—50° N.	Vistula, . . .	65,800	19·908	5·657	3·508
	St. Lawrence, . .	565,200	338·967	87·312	3·904
	Danube, . . .	320,300	198·736	67·511	2·746
	Po, . . .	27,100	23·887	13·322	1·794
	Volga, . . .	592,300	152·384	43·736	3·484
	Seine, . . .	23,250	10·266	5·469	1·877
	Rhone, . . .	34,850	22·439	14·066	1·724
	Dnieper, . . .	197,450	56·093	22·195	2·527
	Loire, . . .	42,600	18·210	7·810	2·332
	Dniester, . . .	30,950	8·792	3·274	2·685
30°—40° N.	Yang-tse-kiang, . .	689,100	408·872	125·043	3·421
	Hoang-ho, . . .	387,150	117·711	28·591	4·159
	Nile, . . .	1,293,050	892·120	24·334	36·998
	Pei-ho, . . .	65,000	22·354	1·650	13·551
20°—30° N.	Mississippi, . . .	1,285,300	673·064	125·603	5·446
	Rio Grande, . . .	232,300	113·655	12·676	8·966
	Indus, . . .	360,050	104·416	26·032	4·886
	Ganges, . . .	588,450	548·791	43·263	16·169
10°—20° N.	Magdalena, . . .	92,900	116·746	59·451	1·964
	Irawadi, . . .	181,950	180·849	82·299	2·256
	Kistna, . . .	81,300	61·025	14·776	4·137
	Godavery, . . .	154,850	95·924	16·841	5·708
0°—10° N.	Orinoco, . . .	429,700	603·397	122·242	4·936
	Equator, . . .	2,229,900	2,833·830	527·951	8·009
0°—10° S.	San Francisco, . .	212,900	218·459	22·197	9·842
	Congo, . . .	1,540,800	1,213·044	419·291	3·213
20°—30° S.	Orange, . . .	267,150	50·913	21·875	2·327
30°—40° S.	Olifant, . . .	14,300	2·472	0·679	3·639
	De la Plata, . . .	994,900	904·687	188·740	6·091
	Uruguay, . . .	151,000	130·890	32·136	4·073
Total		13,272,000	10,186·460	2,182·485	

TABLE VII.—Showing Dissolved Matter in one cubic mile of average River Water, the acids and bases being combined according to the principles indicated by Bunsen.

	Tons per cubic mile.
Calcium carbonate (CaCO_3), . . .	326,710
Magnesium carbonate (MgCO_3), . . .	112,870
Calcium phosphate ($\text{Ca}_3\text{P}_2\text{O}_8$), . . .	2,913
Calcium sulphate (CaSO_4), . . .	34,361
Sodium sulphate (Na_2SO_4), . . .	31,805
Potassium sulphate (K_2SO_4), . . .	20,358
Sodium nitrate (NaNO_3), . . .	26,800
Sodium chloride (NaCl), . . .	16,657

	Tons per cubic mile.
Lithium chloride (LiCl),	2,462
Ammonium chloride (NH ₄ Cl),	1,030
Silica (SiO ₂),	74,577
Ferric oxide (Fe ₂ O ₃),	13,006
Alumina (Al ₂ O ₃),	14,315
Manganese oxide (Mn ₂ O ₃),	5,703
Organic matter,	79,020
For rivers—Total dissolved matter,	762,587

TABLE VIII.—Showing Matter Dissolved in one cubic mile of Sea Water, the acids and bases being combined according to Dittmar.

	Tons per cubic mile.
Magnesium carbonate (MgCO ₃),	438,000
Calcium sulphate (CaSO ₄),	6,147,000
Potassium sulphate (K ₂ SO ₄),	3,723,000
Sodium chloride (NaCl),	117,441,000
Magnesium chloride (MgCl ₂),	16,419,000
Magnesium sulphate (MgSO ₄),	6,529,000
Magnesium bromide (MgBr ₂),	328,000
For sea water—Total dissolved matter,	151,025,000

A cubic mile of fresh water weighs about 4,205,650,000 tons. A cubic mile of ocean water (density 1·026) weighs 4,315,000,000 tons.

BLACK AND MEDITERRANEAN SEAS.

AN interesting paper on the currents between these two bodies of water, and the interchanges that take place between them, is given in the twelfth part of the *Annalen der Hydrographie und Maritimen Meteorologie*, for 1886. The first part of the paper treats of the variations in the level of the Black Sea, based upon observations made at eight stations on its north and east coasts, and spread over a period of eight to ten years. These observations have been worked up by E. von Maydell, whose treatment of the subject is the original source of the following remarks. The second, and much the longer, part of the same paper is occupied with a discussion of the inter-relations obtaining between the waters of the Black Sea and the Sea of Marmora; the observations which have furnished the materials for this discussion were made by Captain Makarof, of the Russian Imperial warship *Tamanj*, in the Bosphorus and the adjacent parts of the two seas in question, his labours extending from November 1881 to August 1882.

With respect to the level of the Black Sea, Herr von Maydell deduces the conclusion that there is not only a series of regular annual fluctuations, but also variations of a somewhat more permanent character, making themselves felt at irregular intervals. These last, however, stand in apparently intimate relation to the variations in the amount of