of Krakatoa in 1883 unusually beautiful red sunsets were visible around the world, due to the fact that in passing through the unusually dusty air the shorter wave lengths were interfered with more than ordinarily, while the red waves got through. The transparency of the atmosphere was reduced to such an extent in the summer of 1912 following the eruption of Mt. Katmai that the quantity of heat available to warm the earth was lessened ten per cent by the haze. This loss was in part offset by a decrease of the earth's radiation to space, likewise due to th haze. The dust layer affected terrestrial temperatures particularly in high latitudes. Finally after the tremendous eruptions of Soufriere, Mayon and Tomboro, 1813-15 came the well-known "year without a summer, 1816," during which frost occurred in every summer month in much of New England.[26]

The amount of heat reaching the earth's surface is dependent not only upon the character of the atmosphere, but on the changes in amount of heat emitted by the sun as well.

[26] Milham, W. I.: The Year 1816—The Causes of Abnormalities, Amer. Met'l. Society, Dec. 31, 1924, to be published in *Monthly Weather Review*.

SOLAR CLIMATE

By FRANCES V. TRIPP

Insolation Without an Atmosphere

Climate, in so far as it is controlled by the amount of solar radiation which any place receives by reason of its latitude, is called solar climate. True solar climate presupposes a globe on which there are neither water nor atmosphere. On such a globe, every place on the same latitude line would have the same climate, because all would receive equal amounts of sunlight. Insolation at any place would be dependent upon two factors, the angle of the sun's rays, and the number of hours the sun remains above the horizon.[1]

The following table shows the distribution of insolation at the upper limit of the atmosphere.[2]

	Equator	20°N	40°N	60°N	North Pole	South Pole
Vernal equinox	1.000	0.940	0.766	0.500	0.000	0.000
Summer solstice ...	0.882	1.044	1.107	1.093	1.201	0.000
Autumnal equinox .	0.987	0.927	0.756	0.494	0.000	0.000
Winter solstice	0.941	0.676	0.357	0.056	0.000	1.283
Annual total	348	329	275	198	144	144

This table also shows that the maximum insolation is greater at the South Pole than at the North Pole. This condition results from the fact that the earth is nearer the sun during the summer of the southern hemisphere, while it is farther from the sun during the summer of the northern hemisphere.

In other words the solar climate of the southern hemisphere is more severe than that of the northern hemisphere, for in the former the sun is nearest the earth when its rays are most nearly vertical, and farthest

[1] For a full discussion of this point, see Ward, R. DeC.: Climate, pp. 7-16; and Hann, J.: Handbook of Climatology, Part I, ch. 6.
[2] Humphreys, W. J., *Mo. Weather Review*, Dec., 1920, p. 708.

away when they strike slantingly. In the northern hemisphere, on the other hand, the nearness of the sun makes the winter climate in clear weather notably warmer than it would otherwise be, and thus exerts a tempering influence in spite of the fact that the obliqueness of the rays prevent all of the 7 per cent increase in heat at this time from reaching the surface.[3]

Insolation With an Atmosphere

Such a climate is, of course, hypothetical. If atmosphere with its water vapor and impurities be added to the globe, important changes result. Since the atmosphere weakens those rays of the sun which pass through it, about one-half of the solar radiation being lost even when the sky is clear,[4] and since the more oblique the rays the thicker the blanket of atmosphere through which they must pass, the amount of insolation is everywhere weakened, particularly in the higher latitudes. The pole no longer has a maximum at the summer solstice. Figures 2 and 3 in Ward's *Climate* which illustrate respectively the annual variation of insolation at different latitudes (without atmosphere) and the insolation received at different latitudes on June 21 with various coefficients of expansion are extremely helpful in clarifying this point.

Of the solar radiation which does not reach the earth, some is absorbed by clouds and by the atmosphere, much is reflected, and becomes sky radiation and sky light. The earth receives its heat then from both direct and indirect sunlight. The amounts of radiation received by the earth's surface vary with (1) latitude, (2) altitude, and (3) season.

1. "Normal temperatures decrease with increase in latitude, except just north of the equator, nearly 1° F. for each degree of latitude (about 1° C. for each 2° of latitude) because insolation diminishes as the angle at which the sun's rays strike the surface of the spherical earth becomes smaller. With this change there is greater reflection, an increase in the area over which a bundle of rays is spread, and of chief importance an augmentation of the distance which the rays must travel in penetrating the atmosphere. Rays entering the atmosphere at a small angle often are reflected away from the earth. Penetration is also reduced by atmospheric absorption and diffraction or scattering of light rays.

"The average air temperature at the surface of the earth is about 59° F. (15° C.); near the equator it is about 80° F. (27° C.) or above, except on the Pacific Ocean where it is about 77° F. (25° C.). The average along the tropics is about 74° F. (23° C.); in mid-latitudes it is perhaps 50° F. (10° C.), and in polar areas 10° F. (—12° C.) or less."[5]

2. "Normal temperatures fall with increase in altitude about 1° F. for each 330 feet (1° C. for 600 feet). The rate differs somewhat for mountains, plateaus, and plains, being 1° F. for each 265 feet of ascent on mountains, 290 feet on plateaus, and 365 feet on plains."[6]

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[3] Brooks, C. F.: Why the Weather, p. 271.
[4] Hann, loc. cit., p. 106.
[5] Visher, S. S.: Climatic Laws, p. 16. For more detail regarding mean temperatures, see Hann-Suring: Lehrbuch der Meteorologic, 4th ed., pp. 135-152, including maps. (For convenience these quotations are made from Visher's summary rather than from original sources.)
[6] Visher, loc. cit., p. 20.

With reference to human comfort this decrease is, however, offset to a certain extent by the increased insolation which occurs at increasing altitudes. This increased warming power of the sun at high elevations makes mountain resorts popular in winter and spring. The intensity of insolation is clearly demonstrated to people going to high altitudes for the first time at any season by the ease and rapidity with which their skin becomes sunburned Langley in his account of an expedition up Mt. Whitney in 1882 says,[7] "As we slowly ascended and the temperature of the soil fell to the freezing point, the solar radiation became intenser, and many of the party presented an appearance as of severe burns from an actual fire."

3. "Seasons of temperature occur in middle and high latitudes because of the revolution of the earth about the sun, and the constant inclination of its axis to the plane of its orbit. The hemisphere tipped toward the sun receives more vertical and nearly vertical rays than the other, and hence is warmer. In other words, the north-south shifting of the zone of greatest insolation accompanying the revolution of the inclined earth produces most of our changes of season. For example, in the United States, Minnesota receives six times as much radiation per unit area on June 21 as on December 21, and Louisiana two and one-half times as much on June 21 as on December 21. During a year, a unit area in Louisiana receives seven per cent more radiation than one in Minnesota, receiving 36 per cent more in the colder six months, but 11 per cent less in the warmer three months. In July, Minnesota receives 20 per cent more than Louisiana. The arid southwest receives almost twice as much radiation as the northeast in winter, and nearly 25 per cent more in summer. The highest average amount received in gram calories per minute per square centimeter is 700 on June 21 in the arid southwest. The lowest is a little less than 100 on December 21 along the northern border in the Great Lakes region."[8]

When one stops to consider the important rôle played by the sun, he cannot fail to realize how natural it is that sun worship should have been practiced so generally among primitive peoples all over the world. For example, in India the sun was worshipped from the earliest period; among the aboriginal Americans it was the supreme god; in the Chaldean system it occupied the central position among the seven circles of the universe.[9]

Without such modern conveniences as electric lights and steam heat they had brought before them daily the fact that the sun, and the sun alone, provided them with light, heat, and indirectly with food. We, on the other hand, do not stop to consider its importance except on unusually cold, hot, cloudy, or bright days. Gray skies are depressing; overcast winter days seem colder than they really are, and necessitate an increased use of artificial light. The length of time snow remains unmelted depends largely upon exposure to sunlight. Streets on northern slopes may be unsafe for traffic long after those on south facing slopes are bare.

[7] *Nature*, (London), Aug. 3, 1883, p. 315.
[8] Visher, loc. cit., p. 24.
[9] Hopkins, S. W.: Origin and Evolution of Religion, New Haven, 1923, Ch. V, pp. 58-67.

The following quotation demonstrates the effectiveness of the sun as an auxiliary to the furnace. "Some of those who bewail the high cost of coal would do well to consider the low cost of sunlight for heating purposes. Some observations in a house which had been vacant for a month (in winter) may be cited by way of advertising the heating power of spring sunlight. When the house was opened about three P. M. on a clear day, the temperature outdoors was 46; in the first floor rooms, somewhat sunny, 50; while in a small conservatory the temperature was comfortably high, about 70."[10]

People building houses on the north side of a street often take advantage of this free heat, and design their houses so that the living room will be on the sunny back, the kitchen and stairway on the sunless front.

In mountain districts human settlements are usually found at greater elevations on the sunnier slopes. "It is reported that in the Oetz Valley in the Alps, considerably more than 75 per cent of the population live on the sunny side of the valley. In fact a certain distinction of classes results from this difference. There is developed an aristocracy of the sun, so to speak. The people on the sunny side are, on the whole, more prosperous and better educated, and look with some contempt upon the people of the shady side."[11]

Furthermore in the matter of city planning, solar radiation is an important factor. Dr. Brooks, in his discussion of city planning for Worcester, Mass., says.[12] "Sunshine (in winter) is of the greatest value for house heating in the morning. Therefore the best locations have SE. slopes, such that the exposure of the house is greatest in that direction and least in the sunless direction. Sunshine in summer as well as in winter is most welcome in the cool of the morning, but since the sun rides high in the sky at this season the advantage of the SE. slope is relatively less than in winter. The afternoon sunning on SW. and W. slopes, however, offsets appreciably the cooling by the wind. Best residential conditions should be found on the SE. and S. slopes—above the reach of the cold air accumulations of the valley bottoms. Second best residential locations may be designated as those on SW. and E. slopes, and in the narrow strip comprising one-third of the slope below the best areas."

[10] Brooks, C. F.: Why the Weather? No. 295, 1924. A Science Service Feature.
[11] Ward, loc. cit., pp. 304-305.
[12] Brooks, C. F.: Local Climates of Worcester, Mass., as a Factor in City Zoning: *Bull. Amer. Met'l. Society*, June-July, 1923, pp. 83-86.

HELIOTHERAPY [1]

By FRANCES V. TRIPP

Heliotherapy, in the words of Dr. Rollier, is as old as the sun itself. Throughout the ages man has exposed to the sun objects he wished to cleanse. Disease and death have always been most frequent in the narrow, sunless, poverty filled alleys of city slums. It was not until well into the twentieth century, however, that heliotherapy began to be applied extensively and in a systematic way to cases of rickets in chil-

[1] This discussion is based on A. C. Rollier's *Heliotherapy*, London, 1923, ch. 7.