loons. This note is concerned chiefly with the mean thickness of cloud layers. The results for the different cloud types are as follows:

Stratus.—Thickness less than 400 meters in greatest number of cases; very seldom greater than 600 meters; mean thickness, 320 meters. There appears to be little seasonal difference.

Nimbus.—The difficulties of observation are very much greater, but the mean thickness of 800 meters is obtained. This is based on a smaller number of observations, due to the fact that under conditions when nimbus prevail, ascents are difficult.

Cumulus.—89 observations gave a mean thickness of 500 meters.

Strato-cumulus.—This layer presented easier determinations because of the attendant discontinuities in temperature and humidity; layers less than 500 meters in thickness were predominant; mean thickness, 310 meters.

Alto-cumulus and alto-stratus.—It is seldon that this level was attained by the registering instruments, and often the clouds were of such a flaky character as to render determinations of thickness difficult; mean thickness for A. Cu., 120 meters, for A. St., 300 meters.

On the whole these values are not in bad agreement with those of Süring at Potsdam. From these means, and from the mean heights of the lower surface of the various cloud types, it is possible to construct a schematic vertical section of the atmosphere above Lindenberg. This the author does, and it appears that there are three layers in which the clouds do not frequently occur—designated by Wenger and Köppen as *wolkenfrei Räume.* These are (1) from the surface to 500 meters; (2) between 1,300 and 1,400 meters—this level being somewhat in doubt; and (3) between 1,900 and 3,000 meters. Too much weight is not given this diagram by the author, and he remarks that "it has only the value of a schematic representation of a cloudy day, but, owing to the numerous observations, it probably approaches closely to the truth."—*C. L. M.*

ANALYSIS OF CLOUD DISTRIBUTION AT ABERDEEN, SCOTLAND,[1] 1916–1918.

By G. A. Clarke.

[Reprinted from *Science Abstracts*, Sec. A, Jan. 31, 1921, §26.]

The cloud distribution is analysed from the point of view of aerial navigation. Cloud observations are taken at Aberdeen at 7h., 9 h., 13 h., 15 h., 18 h., 21 h., and to each day is assigned in addition a "cloud characteristic" indicating the kind of cloud which predominated, the lowest type taking precedence over higher ones if covering four-tenths of the sky or more. The day is "clear" if on the average the total amount of sky covered is less than four-tenths, while certain days of very mixed or rapidly changing cloud are classed as "various." Taking cumulus and cumulo-nimbus together, they are found to give the most frequent skies, 23 per cent of the total, while other low clouds are numerous. Alto-stratus skies are twice as frequent as alto-cumulus, but cirro-stratus and cirro-cumulus skies are of equal frequency. Using the average heights of the various types together with the cloud characteristic, 15 per cent of days are seen to be cloud-free below 15,000 feet, 26 per cent below 7,000 feet, 69 per cent below 3,000 feet, while the remaining 31 per cent of days have cloud predominating below 3,000 feet. Seasonal distribution is discussed. The frequency of cumulus and cumulo-nimbus taken together is found to be greatest in April, and there are secondary maxima in mid-summer and September. Air conditions should be most bumpy at these periods. Strato-cumulus skies are more common in winter than in summer, and there are indications that skies well covered with intermediate and higher clouds are also more frequent in winter, but the observations depend on the presence or absence of lower cloud.—*M. A. G.*

[1] Meteorological Office, London, *Professional Notes No. 9*, 1920, pp. 142–147. Cf. also, Brunt, D.: On the inter-relation of wind direction and cloud amount at Richmond (Kew Observatory), *ibid.*, No. 1, 1918, 11 pp.; Diagrams illustrating the amount of cloud during summer and winter with winds from different directions, at Kola and Archangel, *ibid.*, No. 7; The Climate of Northwest Russia, 1919, p. 94; Brunt, D.: Tables of frequencies of surface wind directions and cloud amounts at Metz, Mulhausen, Karlsruhe and Frankfurt, *ibid.*, No. 14, 1920.

THE ARGONNE BATTLE CLOUD.

By B. M. Varney.

[University of California, June 22, 1921.]

Descriptions of unusual clouds that were formed in the wakes of airplanes flying over the Argonne battle front in the autumn of 1918 has since been published by eyewitnesses. Mr. G. B. Vaughn wrote [1] as follows:

> We were passing through a little town * * * when we noticed three parallel lines of clouds or smoke stretching far across the sky. They looked as if they had been made by three planes passing, throwing out smoke and cutting stunts, for the lines were far from straight. Through these lines were waves which ran perpendicular to the earth, with a drift from left to right. They looked most like waves of heat one sees rising from the earth, but they traveled with a shifting motion somewhat like the flickering of the northern lights.

Capt. W. F. Wells, Sixtieth Infantry, American Expeditionary Forces, wrote: [2]

> There were two or three days of rain, when came a wonderfully clear and beautiful morning, with not a cloud in sight. * * * Our attention was first drawn to the sky by the sudden appearance of several strange and startling clouds—long, graceful, looping ribbons of white. These were tapering to a point at one end, and at the other, where they dissolved into nothingness, sixty degrees across the sky, were about as broad as the width of a finger held arm's distance from the eye. On close observation we noticed some distance ahead of each cloud point the tiny speck of a chase plane. Apparently the churning of the air was all that was needed to upset the delicately balanced meteorological conditions and precipitate this strange cloud formation. * * * Never before had I seen a plane writing in white upon the blue slate of the sky.

Capt. W. H. Nead, One hundred and sixty-eighth Infantry, described the phenomenon [3] thus:

> The Rainbow Division, on the morning of October 10, 1918, was lying in what had at one time been a wood just back of Montfaucon. The sky was clear except for a few fleecy clouds to the northwest. Three airmen came from the northwest and passed almost over our regiment, continuing on to the southeast.
>
> Behind each machine was a trail of white, which at first sight appeared to be smoke resulting from poor engine combustion, but which upon more careful observation proved too wide to have been caused by smoke. Perhaps the strangest thing of all was the fact that when the planes reached a certain point in the sky the rainbow (sundog) colors became distinctly visible.
>
> The explanation is not difficult. The air was almost saturated with moisture at the temperature which prevailed at that altitude. With the passing of the planes, the propeller movements caused a strong air current with a lowering of the temperature where the current was noticeable. With the lowering of the temperature the air became supersaturated with moisture, forming a small cloud, which at that altitude immediately became snow. This snow would give the white appearance * * * and would also account for the rainbow colors.

The attainment of the saturation point being necessary to condensation, the methods by which this may be

[1] *Am. Legion Weekly*, Sept. 24, 1920, p. 28.

[2] *Scientific American*, June 7, 1919.

[3] *Am. Legion Weekly*, Oct. 22, 1920, p. 12.

brought about in this particular case are of interest. It could scarcely be the result of a reduction in temperature due to the stirring, *per se*, of the air by the propeller. An increase in the moisture content of the air is probably involved. Of the two following suggestions as to the origin of the cloud the first, and probably the correct one, was made by Prof. Humphreys:

> The end products of complete combustion of gasoline are water vapor and carbon dioxide, and it is found that if the water vapor were condensed, there would result a little more than 1 gallon of water per gallon of gasoline consumed. It was found by Wells and Thuras, in studying the fogs off the Newfoundland coast (see *U. S. Coast Guard, Bull. 5*, 1916) that there were 1,200 water droplets of diameter 0.01 mm. in a cubic centimeter of air in a dense fog. If we assume that an airplane travels 3 miles on a gallon of gasoline (approximately the figure given by the Aerial Mail Service) it is possible to show that if only a small part—a fourth or fifth—of the water vapor were condensed, there would be abundant cloud to produce the effect observed at the Argonne Battle. It should be stated, however, that this water vapor would have to be discharged into air which was very cold and nearly saturated. This seems to be the correct explanation, and is substantiated by scientists at the Bureau of Standards, who say that they have actually observed this cloud behind airplanes and automobiles. The Bureau of Standards is working on a device for condensing and using this water aboard dirigibles as ballast.

The second suggestion, by the writer of this note, is in harmony with experimental results, though whether the necessary conditions can exist in the free air is a question. It is suggested that it may be possible for supersaturation to occur in the atmosphere and for shock of some sort to induce condensation in air in which this unstable condition exists. Color is perhaps lent to this speculation by the facts that condensation has been induced, experimentally, in supersaturated air, by shock, and that the supercooling of water droplets is a recognized process in the free air. Mr. K. C. M. Douglas has shown[4] "that clouds consisting of supercooled water droplets may exist more than 10,000 feet above clouds consisting of ice crystals," and at temperatures at least 43° F. below the freezing point of water, and that shock of impact with his plane caused the instant freezing of the droplets. In the case of the Argonne Battle cloud, the question is therefore raised as to whether supersaturation can occur in the free air, and whether atmospheric vibrations set up by the exhausts from the engines would be a sufficient cause of condensation in such air. If such were the case, the volume of air involved would doubtless be great enough to furnish water vapor sufficient to form a visible cloud.

[4] Douglas, C. K. M.: Optical phenomena and the composition of clouds. *Jour. Scot. Met. Soc.*, Vol. XVIII, 3d series No. XXXVI, pp. 83-86.

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FROST SUPERSATURATION (FROSTÜBERSÄTTIGUNG) AND CIRRUS.

By ALFRED WEGENER.

[Abstracted from *Meteorologische Zeitschrift*, Jan.-Feb., 1920, pp. 8-12.]

It is possible to find conditions of vapor pressure and temperature, in which the space over ice is saturated, but over under-cooled water at the same temperature it is not saturated. The author has given this condition the name *Frostübersättigung*, or frost supersaturation. There exists a point, known as a triple point, at which water, ice, and undercooled water may exist side by side. The coordinates of this point are e (vapor pressure) = 4.57 mm., and t (temperature) = +0.0075° C. At temperatures below this point evaporation will cease to take place from an ice surface at a slightly lower vapor pressure than from an (undercooled) water surface at the same temperature. In other words, over a small range of vapor pressure condensation may be occurring on ice at the same time that water at the same temperature is evaporating. The point of maximum difference of vapor pressure, amounting to 0.2 mm., occurs at a temperature of −11.4° C.

Some of the consequences of this physical relation are pointed out. It has often been observed in free-balloon ascents that, above the 0° C. isotherm, undercooled water droplets and snow crystals may simultaneously occur. But the water droplets are evaporating and the snow crystals are growing larger, with the result that water eventually disappears. This is the spectacle afforded by the streaks of falling snow above which the mother cloud has entirely evaporated.

Many observations have been made in Greenland of cases in which the air has been supersaturated with respect to ice but not to water. The result has been that large crystals of ice have been seen to form on the snow. In addition, occasionally with a higher relative humidity, fog has formed after the ice crystals have appeared. In the case where this crystal-forming stage has been followed by a rise in temperature and a consequent fall in humidity, the ice crystals have disappeared. This phenomenon can occur in clear weather.[1]

The author gives other examples: On a day with a temperature of −40° C., a cloud 3 km. in length was seen in Greenland, stretching away from a chimney. During three airplane flights over Munich at a height of 9 km. a cloud 50 km. in length was formed. That it was composed of ice crystals was proved by the fact that the 22° halo was observed. This cloud the author attributes to the nuclei furnished by the motor exhaust.[2] A horse, warm from running over the ice, on a cold day in Greenland, was accompanied by a cloud 50 meters in height formed from its breath. Von Hann gives a similar case regarding a herd of reindeer. The human breath also has been seen to transform itself into small clouds of ice needles. These are also attributed to nuclei discharged into the air.[3]

The condition of frost supersaturation may be responsible for the apparent self-sustaining nature of cirrus wisps. It may be that the cirrus particles, forming at high elevations fall into supersaturated layers. The crystals of the cirrus act as nuclei for growth, and the consequence is that the layer changes from a state of supersaturation to one of saturation and the cloud appears to spread out and become heavier merely by virtue of the ice formed upon the falling crystal.—*C. L. M.*

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ON THE FREQUENCY OF FOGS IN THE EASTERN SAHARA.

By J. TILHO.

[Abstracted from *Comptes Rendus*, Paris Acad., June 14, 1920, pp. 1435-1438.]

It has often been observed that during December and January the west coast of Africa, particularly that in the vicinity of the Gulf of Guinea, is visited by northeast winds accompanied by persistent fogs, which seemed to be constituted quite largely by fine dust particles sup-

[1] Such frost can also form when the ice-surface temperature is below the (ice) dew-point of the air—without frost supersaturation in the space above the ice.—EDITOR.

[2] Capt. Walter H. Nead in the *American Legion Weekly* of Oct. 22, 1920, relates the formation of long cirrus clouds in the wake of three airplanes in the vicinity of Montfaucon, France, on Oct. 10, 1918. At first the trails were thought to be smoke, but they proved to be too wide for smoke. Their ice-crystal structure became evident when halo phenomena were observed as a result of their presence. Cf. "The Argonne Battle Cloud." This REVIEW, pp 348-349.—EDITOR.

[3] The moisture without the nuclei discharged would be ample to make such clouds, therefore, the nuclei merely assure the formation of the cloud which would probably form anyway.—EDITOR.