to produce the squall, and at the same time not interfere with the incoming currents above, seems hard to understand. For it could not "kick" at all unless its pressure be increased; and if its pressure be increased, it would "kick" in all directions, and would "kick" back the incoming currents and prevent them from entering the storm area at all. The surrounding air could not enter until the high pressure had given way to lower pressure; but when this takes place, the high pressure on the ground would also give way to lower pressure, and the squall would cease. But, in fact, both the inflowing currents above and the outrushing squall below blow with comparative uniformity, thus showing that there are some sort of constant barometric conditions established, which insure a low pressure above and a relatively high pressure below.

(3) The "convectional overturn" theory has the same weakness that the "kick" theory has, because (*a*) the upper air could not "overflow" until its pressure be greater than that of the surrounding air; (*b*) if the overflowing air above has relatively greater pressure, it will produce greater pressure below also, unless the column is abnormally warm or light, and we should have the anomaly of air rising into relatively higher pressure and settling in lower pressure.

The explanation which I wish to suggest is based on the well-known coolness of the air in the squall. Under uniform pressure, the density of the air decreases 1/491 of that at 32° F. for every degree Fahrenheit above the freezing point of water.

We will suppose the distance from the thundercloud to the ground to be 1,300 feet (it may be more), and suppose, also, that the air between the cloud and ground is, on an average, 15° F. cooler than the surrounding air (it is often considerably more). It may easily be found that the difference in weight of these two columns of air (each 1,300 feet high) would be about 0.04 inch of mercury, that is to say, placed side by side, the cool column would support 0.04 inch more mercury than the warm column would. Evidently, if the air be much cooler (say 35° F.), and if the height of the cool column be several thousand feet, the difference in weight would be much more marked. The presence of this cool column of air, then, extending from the cloud to the ground, will account for the higher air pressure below. But not only this, it will account, also, for the permanent low above. If a series of isobars be drawn in a vertical plane section through the thunderstorm, the isobaric surfaces will crowd together in the cool column and be farther apart in the surrounding region of warm air. The higher pressure below will suffice to produce the squall, and the lower pressure above will permit convection to go on undisturbed.

The rise in barometer during the passage of a thunderstorm is usually very slight. I have often noted, in well defined storms, a rise of not more than 0.03 inch. In very violent storms, however, the rise may be considerably more, as much as 0.15 or even 0.25 of an inch. But it is a notable fact that in these violent storms, the drop in temperature is very marked. This is just what we should expect if the "cold air" theory is true. I have yet to hear of a thunderstorm accompanied by a typical squall in which the air of the squall was warmer than the surrounding air.

The "cool air" theory will undoubtedly suffice, provided only the cool air column is present. And as indications that the column of cool air does exist, we mention the following: (1) The internal air of the squall is considerably cooler on the ground. (2) The fact that the so-called wind cloud is usually much lower than the other convectional clouds which are fed from air of like temperature and humidity, shows that the rising air meets with relatively cooler air below the margin of the cloud.

There are, of course, several things to be remembered in applying this "cool air" theory. Confessedly there are still a good many "unknowns" in the thunderstorm; but the following will evidently modify and determine the violence of the squall. (1) The average difference of temperature between the cool column and the surrounding air. (2) The height of the cool column. (3) The diameter of the cool column. (4) The progressive motion of the storm itself. No one of these four will alone determine the violence of the squall. In general, the intensity of the squall will vary directly with the relative coolness of the column, its height, and its diameter. But these factors may vary considerably among themselves, and there can be no narrow, cast-iron rules laid down. We should expect to find the squall strongest when these factors combine and weakest when they are weak.

The progressive motion of the storm will affect the squall somewhat, making it apparently stronger in front than behind.

As to the origin of the cold air of the squall there is some diversity of opinion. By some it is thought that the coolness of the air is due to cold rain falling through it. In many cases this seems a sufficient explanation. Thunderclouds probably often extend above the snow line. The melting of this snow, the warming of the cold water in its descent, and the resulting evaporation of some of it, might well keep the air through which it falls several degrees cooler than the outside air. The amount of air that rises into the thunder cloud is apparently several times greater than that which blows out from it below. The falling snow and rain cool a comparatively small amount of air beneath the clouds.

Cool squalls in the absence of rain are thought to be caused by the settling of overlying masses of air that are intrinsically and abnormally cold. This is entirely probable. It is generally supposed that thunderstorms, especially those accompanied by tornadoes, are overlaid by layers of cold air. But it is more probable, I think, that many of the wind clouds, unaccompanied by rain, are the last remnants of former thunderstorms, or are the products of actions that were too feeble to produce a thunderstorm.

It seems pretty certain that the circulation of air in an active or "typical" thunderstorm is as about as follows: The air from around rises toward the cloud; the inner layer of this ascending air meeting with the falling snow or rain is cooled, and also pushed down by the rain drops; both cooling and pushing cause it to be turned downward. And as it is more and more cooled (i. e., relatively), and continually beaten down by the falling rain, it settles more and more rapidly, and on reaching the ground becomes the cool outrushing squall. The presence and the appearance of the so-called "wind cloud" that generally just precedes the rain cloud, seems to indicate this. It is a long light-colored fleecy cloud that suggests a huge roll of wool. A cloud formed at the level where the rising air turns to descend would have an appearance like this.

## A METEOROLOGICAL BALLOON ASCENSION AT STRASBURG, GERMANY.

By A. LAWRENCE ROTCH, Director of the Blue Hill Observatory, dated Aug. 7, 1901.

Through the courtesy of Professor Hergesell, the President of the International Aeronautical Committee, the writer (who is the American member of the Committee) participated in the eighteenth series of balloon ascents on July 4, 1901, when balloons were dispatched from Paris, Berlin, Strasburg, Munich, Vienna, and St. Petersburg. The manned ascension from Strasburg was made by Professor Hergesell and the writer in the new cotton balloon "Girbaden," of 1,300 cubic meters, belonging to the Aeronautical Society of the upper Rhine. On this occasion this balloon was filled with coal gas and had a lift at starting represented by sixteen sacks of ballast weighing together about 300 kilograms.

Two *ballons-sondes*, one of paper the other of silk, carrying self-recording instruments, were sent up at 3 a. m. and 8:35 a. m., respectively. They traveled in a south-southwest direction, but not very far, reaching a maximum height of about 8,000 meters. The "Girbaden" left the ground in a light rain at 9:05 a. m., rose through two strata of clouds to a height exceeding 4,000 meters and after a voyage of a little more than three hours a sudden descent, to escape a threatenstorm, landed us in the Vosges Mountains, near the town of Ammerschweid, a few kilometers northwest of Colmar and about 75 kilometers south-southwest of Strasburg. The observations of temperature and humidity were made every few minutes by Professor Hergesell with an Assmann aspiration psychrometer, hung outside the basket of the balloon and several feet distant therefrom, but drawn near to it for reading, and when it was necessary, to wet the bulb of the thermometer. Simultaneous observations of pressure were made by the writer with a large aneroid barometer, of which the corrections were determined under an air pump previous to and subsequent to the ascension. A portable barograph, belonging to the writer, registered continuously the approximate heights and showed at every moment whether the balloon was rising or falling. The detailed observations follow:

*Ascent of "Girbaden"* (1,300 *cubic meters of coal gas*) *from Strasburg, July* 4, 1901, *with Prof. H. Hergesell and A. L. Rotch.*

| Time. A. M. | Bar. (cor'd) | Height above sea. | Aspiration thermometers. Dry. | Aspiration thermometers. Wet. | Vapor press. | Dew-point. | Rel. hum. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| *H. m.* | *Mm.* | *M.* | ° *C.* | ° *C.* | *Mm.* | ° *C.* | %. | |
| ..... | 756.5 | 0 | 16.5? | ..... | ..... | ..... | ..... | |
| 9 05 | ..... | 143 | 15.4 | 15.4 | 13.00 | 15.4 | 100 | Rose from Steinthor; light rain. |
| 08 | 709.7 | 525 | 12.7 | ..... | ..... | ..... | ..... | Moving south over Strasburg. |
| 10 | 702.3 | 630 | 12.0 | ..... | ..... | ..... | ..... | In clouds. |
| 12 | 695.8 | 720 | 11.4 | 11.4 | 10.08 | 11.4 | 100 | Clouds thinner |
| 16 | 690.6 | 775 | 11.2 | 11.2 | 9.90 | 11.2 | 100 | Four sacks of ballast thrown out. |
| 17 | 685.3 | 830 | 10.9 | 10.9 | 9.70 | 10.9 | 100 | |
| 20 | 679.0 | 925 | 10.4 | 10.4 | 9.39 | 10.4 | 100 | Clouds very thin. Insolation felt. |
| 22 | 672.8 | 1000 | ..... | ..... | ..... | ..... | ..... | Sun appears; we are on upper edge of cloud. |
| 24 | 668.6 | 1055 | 10.3 | 10.1 | 9.11 | 10.0 | 98? | Below us is a sea of clouds; above is a broken cloud sheet, presumably alto-stratus. |
| 27 | 660.8 | 1155 | 9.5 | 9.0 | 8.33 | 8.6 | 94? | |
| 30 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | In north-northwest in neighborhood of Vosges Mountains are turretted cumulus. |
| 32 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | One-quarter sack ballast out |
| 33 | 641.4 | 1395 | 8.2 | 7.8 | 7.71 | 7.5 | 95 | Cloud sea broken, permitting fields and a village to be seen below. |
| 35 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | Three-quarter sack ballast out. We are going parallel with the railway to Basel. |
| 36 | 632.3 | 1500 | 7.5 | 7.1 | 7.35 | 6.8 | 95 | |
| 42 | 618.7 | 1690 | 6.8 | 6.4 | 7.00 | 6.1 | 95 | |
| 43 | 610.1 | 1800 | 5.9 | 5.4 | 6.49 | 5.0 | 94 | One sack ballast out. |
| 54 | 598.0 | 1975 | 4.8 | ? | ..... | ..... | ..... | |
| 56 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | We decide to traverse upper cloud stratum, and throw out one sack ballast. |
| 58 | 586.5 | 2150 | 5.0 | 3.0 | 4.88 | 0.9 | 75 | |
| 10 00 | 583.5 | 2190 | 3.7 | 2.2 | 4.76 | 0.6 | 81 | Cumulus below; the cloud stratum above has become dense stratus. |
| 02 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | One sack ballast out. |
| 06 | 575.4 | 2250 | 3.0 | 2.9 | 5.58 | 2.8 | 99 | Balloon follows exactly the bed of the Ill. |
| 08 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | One sack ballast out. |
| 11½ | 561.4 | 2480 | 2.3 | 2.0 | 5.16 | 1.7 | 96 | We enter upper cloud. |
| 14 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | One sack ballast out. |
| 15 | 555.4 | 2565 | 1.4 | 1.4 | 5.05 | 1.4 | 100 | In clouds; sun faintly seen. |
| 16½ | 545.4 | 2715 | 0.9 | 0.8 | 4.80 | 0.7 | 99 | Upper limit of cloud. |
| 18½ | 540.4 | 2785 | 0.1 | — 0.4 | 4.26 | — 1.0 | 92 | Thermometer of aneroid in sun +19°. Above us is clear, deep-blue sky; beneath us unbroken sea of clouds; in southwest high cumulus summits (cumulo-nimbus) with cirrus. |
| 29 | 515.1 | 3150 | —2.1 | — 2.8 | 3.48 | — 3.7 | 89 | |
| 34 | 508.5 | 3260 | —3.8 | — 4.2 | 3.22 | — 4.8 | 93 | |
| 38 | 506.9 | 3295 | —3.6 | — 4.2 | 3.16 | — 5.0 | 90 | |
| 41 | 500.3 | 3400 | —3.7 | — 4.2 | 3.19 | — 4.9 | 91 | |
| 45 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | One sack ballast out |
| 47 | 490.5 | 3560 | —4.0 | — 4.2? | ..... | ..... | ..... | Wet bulb probably not in order. |
| 50 | 484.3 | 3660 | —4.0 | ..... | ..... | ..... | ..... | |
| 11 04 | 475.6 | 3805 | —4.7 | — 5.7 | 2.68 | — 7.2 | 83 | |
| 11½ | 462.6 | 4060 | ..... | ..... | ..... | ..... | ..... | |
| 13 | 462.1 | 4067 | —7.6 | — 9.2 | 1.79 | —12.3 | 69 | |
| 16 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | One sack of ballast out. |
| 21 | 457.9 | 4120 | —7.3 | —10.5 | 1.09 | —18.3 | 41 | |
| 23½ | 455.3 | 4160 | —6.7 | — 9.4 | 1.43 | —15.1 | 51 | |
| 25½ | 454.6 | 4170 | —6.8 | —10.2 | 1.08 | —18.4 | 41 | Maximum height. Temperature measured several times. |
| 27 | 458.7 | 4110 | —6.8 | — 9.7 | 1.31 | —16.1 | 48 | |
| 36 | 458.7 | 4110 | —6.4 | — 9.3 | 1.38 | —15.5 | 48 | |
| P. M. | | | | | | | | The great cumulo-nimbus clouds approach nearer and nearer, and the gray masses can be seen boiling up. Since there is danger of being drawn into a thundercloud we decide to descend at once. Repeated pulls of the valve cause the balloon to fall rapidly, and in five minutes it reaches the upper cloud stratum and descends quickly through it. Between the two cloud strata there is some sunlight. We sink into the lower cloud that reaches low down and only discover, when near the ground, that we are above the forests of the Vosges Mountains. The balloon rapidly traverses a town, later found to be Kaisersberg. With the drag rope touching the ground we cross the spur of a mountain, between Kaisersberg and Ammerschweir, and land at 12h. 13m. in scrub wood two kilometers from Ammerschweir. Immediately after landing there was a squall, with heavy rain. |
| 12 23 | 725.0 | 365 | 16.0 | 14.6 | 11.67 | 13.7 | 86 | Cumulo-nimbus moving from north-northeast, with rain in mountains. |

## DIURNAL WINDS ON FAINT GRADIENT IN NORTHWESTERN NEW MEXICO.

By Prof. RICHARD E. DODGE, of Columbia University, New York.

The diurnal winds that have been observed during the last three summers in northwestern New Mexico deserve note because of the gentle gradient along which they move. The winds in question occur regularly in the canyon of the Chaco River, one of the southern tributaries of the San Juan River, which is in turn a tributary of the Colorado River. The valley has an east-west extent for nearly ten miles, and it is in this stretch that the winds have been observed, the observer having his station in the middle of the stretch at Pueblo Bonito, now the post office at Putnam, N. Mex.

The valley throughout the stretch in question is a little more than one-half mile in width, and is bordered by mesas averaging 250 feet in height. The north mesa rises nearly vertically for 100 feet, but the south mesa has a gently sloping shale slope at its base that is approximately 50 feet in height. The gradient of the valley in the stretch noted is a little less than ten feet to the mile.

The west wind sets in between 9:30 and 10:30 a. m., and usually about 10 a. m. It may first be noted as a gentle breeze just stirring a flag. The wind increases slightly in intensity as the day advances, reaching a maximum in the early afternoon. After midday local overturnings forming large dust whirls may frequently be observed. From 4 to 7 p. m. the wind usually decreases in intensity, and a dead calm