were of extraordinary size, some being one-half inch in diameter. So heavy were they that many of them were broken in alighting upon my blackboard.

The snowflakes in this storm were so substantial that after the snow ceased I took quantities of them indoors and used them for photographing until nearly noon, when sunlight and rising temperature prevented further work. Although many of the crystals were somewhat deformed by unequal evaporation, the set as a whole is of exquisite beauty—a priceless addition to my series of branching crystals. It will be noted that the general effect of the arrangement of the multitudes of secondary and tertiary degree rays around the axial rays is beautifully symmetrical. Yet a closer analysis discloses that no two of the axial and pendant rays are alike, and that the secondary and tertiary degree rays are not always arranged opposite each other in pairs as is often the case. This suggests colloidal crystallization, the use by the growing crystals, in part, of groups of water molecules not completely subject to crystallographic law.

A thorough analysis of this wonderful series of branching crystals leaves one in doubt as to which ones are the most beautiful and interesting. The drooping pattern of No. 4711 recalls some of the drawings of Glaisher. The downward growth of rays of the third degree in No. 4695 forms a lovely, unique pattern. Very interesting also are the branchy rays arranged as peripheral adornments around the solid centerpiece of No. 4716.

Perhaps most interesting of all is No. 4726, because it shows so beautifully the tendency, so often seen in some form, by many hexagonal crystals, to divide into three. In this specimen it will be noted that the main secondary rays of each alternate axial ray have grown farther than those lying between them, thus forming a triangular effect.

This brief account of the newer "treasures of the snow" will perhaps once more serve to inspire renewed interest in the peerless snow gems and to emphasize the fact that the treasures of the snow are absolutely inexhaustible, almost untouched as yet.

The writer is happy in the thought of having added during recent years so many new snow gems of the "first water" to his already numerous collection of over 4,700 specimens, of which no two are alike. There is much room also for gratification in the fact that there is an ever increasing interest in snow crystals the world over, as proven by the manner in which they are being featured by the press, magazines, lecturers, museums, textbooks, and moving pictures, as well as the new uses of them as designs in the arts, crafts, and industrial sciences.

As the writer looks back 44 years to the beginning of his seemingly unimportant study of snow crystals, it seems to him remarkable that the work should have produced such undreamed of results. Perhaps it is not too much to say that the results of his studies form one of the "little romances of science."

C. E. P. BROOKS[1] ON THE EFFECT OF FLUCTUATIONS OF THE GULF STREAM ON THE DISTRIBUTION OF PRESSURE

By A. J. HENRY

It has been recognized for many years that in one way or another the Gulf Stream affects the weather of western Europe but in just what way is not so definitely known.

Doctor Brooks seeks the answer by means of a very comprehensive statistical comparison between fluctuations in the strength of the Gulf Stream and the subsequent weather.

Data as to the volume and temperature of the Gulf Stream not being available the author goes back a step to the causes which must produce variations in the volume and temperature of the water of the stream, viz, to variations in the NE. and SE. trades of the Atlantic Ocean. These as is well known give rise to the Gulf Stream. Since in its travel of several thousand miles there is the possibility that its temperature may be influenced by one or more variables along its course it was necessary to investigate the subject under the following heads:

1. NE. trades.
2. SE. trades.
3. Pressure at Habana.
4. Pressure difference Bermuda—Charleston.
5. Pressure difference Bermuda—Sydney.
6. Pressure difference Azores—Iceland.
7. Pressure difference Stornoway—Iceland.

At the outset the author investigates the rate of flow of the various branches of the Atlantic circulation and presents the results shown in Table 1 below. The rates and speeds shown are of course only the roughest approximations, yet they serve to give an idea of the time required for variations in the currents in one part of the Atlantic to be propagated along the course of the currents to other parts of the ocean.

TABLE 1.—*Speeds and times of Norh Atlantic circulation*

Current	*From—*	*To—*	Distance (nautical miles)	Speed, (miles per day)	Mean time in days
North Equatorial	16° N., 25° W.	16° N., 60 °W.	1,900	17	112
Antilles	16° N., 60° W.	23° N., 75° W.	850	12	71
South Equatorial	St. Helena	5° N., 40° W.	2,800	20	140
Guiana Current	5° N., 40° W.	20° N., 80° W.	2,400	35	69
Yucatan to Florida Strait	Round	Gulf of Mexico.	(500)	(20)	(25)
Gulf Stream:					
Florida Strait to Cape Hatteras.	23° N., 80° W.	36° N., 75° W.	600	70	9
Cape Hatteras to Newfoundland.	36° N., 75° W.	42° N., 50° W.	1,200	38	32
Newfoundland to Azores	42° N., 50° W.	40° N., 26° W.	1,200	10	120
Newfoundland to north of Scotland.	42° N., 50° W.	60° N., 5° W.	1,800	12	150

The initial assumption is that the effect of the various factors, trade winds, pressure differences, etc., are caused mainly through temperature variations carried along by the Gulf Stream and the Gulf Stream drift.

Correlation coefficients were first computed between the velocity of the NE. trade and subsequent pressure over western Europe, the final objective being, of course, the discovery of a relation that might be useful in long-range weather forecasting.

The following-named stations were used to represent the pressure over western Europe: Jacobshavn (west coast of Greenland); Stykkisholm, Iceland; Thorshavn, Faroes; Ponta Delgada, Azores; Valencia; Paris; Berlin; Bergen and Vardo, Norway.

The pressures at these stations were correlated with the trade wind velocities for the same quarter, for the preceding quarter, and so on over a period of two years. In addition to the regular quarterly coefficients representing intervals of 3, 6, 9, . . . months pressures were also correlated with the velocities of the trade wind four months earlier—i. e., pressure January to March with velocity

[1] Air Ministry, Meteorological Office, Geophysical Memoirs No. 34, by C. E. P. Brooks, D. Sc.

in the preceding September to November, pressure April to June with velocity December to February, and so on. This was because a tendency was suspected for the coefficients to reach a maximum or minimum with an interval of four months.

The quarterly coefficients between the velocity of the NE. trade and the subsequent pressure at the eight stations above named are given in Tables 3 and 5 (not reproduced) for both NE. and SE. trades and for lags of 3, 4, 6, 9, 12, 15, 18, 21, and 24 months.

From the tables the following conclusions are drawn. (Places in bold face type have coefficients of ±0.20 or greater.)

CHANGES FOLLOWING A HIGH VELOCITY OF THE NE. TRADE

After four months, high pressure at **Jacobshavn**, Stykkisholm and Vardo; low pressures at Ponta Delgada, Valencia, Paris, and Berlin.

Nine months, high pressure at **Jacobshavn**, Thorshavn and Vardo; low pressure at **Ponta Delgada.**

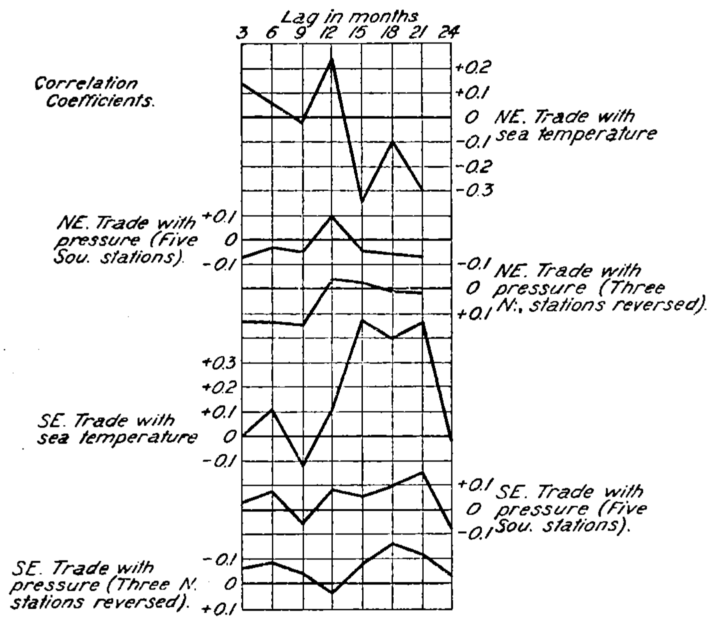

FIG. 1

Twelve months, high pressure at Valencia, Paris, Berlin, and Bergen; low pressure at Vardo.

Fifteen months, low pressure at Bergen and Vardo.

Eighteen and twenty-one months, high pressure at Jacobshavn; low pressure at **Ponta Delgada.**

CHANGES FOLLOWING A HIGH VELOCITY OF THE SE. TRADE

After three and six months, high pressure at Paris and Berlin; low pressure at Stykkisholm.

Nine months low pressure at Stykkisholm, Thorshavn, Valencia, Paris and Berlin.

Twelve months, high pressure at Jacobshavn, Stykkisholm, Thorshavn, Valencia, **Paris** and Berlin; low pressure at Ponta Delgada and Vardo.

Twenty-one months, high pressure at **Valencia, Paris** and Berlin; low pressure at Vardo.

Discussing these results the author finds that after 4 months the water which the NE. trade drives is in the neighborhood of the Antilles, after 9 months in western mid-Atlantic, and after 12 months in the longitude of the Azores. The further observation is made that since depressions which influence the pressure over western Europe often originate over the western Atlantic, the occurence in western Europe 9 or 12 months after the occasion of an abnormal wind velocity is intelligible but the effect with a lag of 4 months is not understood.

Water set in motion by the SE. trade at St. Helena will be found 9 months later off Newfoundland and 12 months later in mid-Atlantic. After 21 months it will either be in the Artic Ocean or will have partially completed a second circuit of the Atlantic, according to which major branch of the Gulf Stream drift it follows. Here again the effect at 9 months is intelligible but not at 21 months. It is remarked that the correlation coefficient between NE. and SE. trades is only +0.26.

Correlation of NE. and SE. trade with subsequent sea-surface temperature—Florida to Valencia—is next made. Fluctuations in both the strength of the trades and in sea-surface temperatures collected by Hepworth for the five years 1902–1906 were each combined in sets of three months and were correlated. The results are shown in Table 2 below.

TABLE 2.—*Correlation of NE. and SE. trade with subsequent sea-surface temperatures—Florida to Valencia*

	Lag in months							
	3	6	9	12	15	18	21	24
NE. trade	+0.13	+0.06	−0.02	+0.24	−0.35	−0.10	−0.29	....
SE. trade	+.01	+.11	−.12	+.11	+.48	+.40	+.47	−0.03

As shown by the above the maximum positive effect of the NE. trade on surface temperature is experienced after a lapse of 12 months; it is not very definite and is followed at 15 months by a more pronounced negative effect. The author further remarks that the maximum effect of the SE. trade is better shown and extends from the 15th to the 21st month.

This difference in the duration of the warming effect due to the two trade-wind systems is probably due to the difference in the configuration of the Atlantic Ocean north and south of the Equator. Owing to the great bulge of west Africa the NE. trade wind blows to a large extent off the coast. Hence a strong NE. trade soon drives into the North Equatorial Current all the available supply of warm surface water; the place of the latter is taken by relatively cold water, which is brought to the surface near the coast from the lower layers of the ocean. The SE. trade on the other hand blows almost parallel to the coast and drives before it the warm surface waters from a wide area, without bringing up the colder layers from below.

This difference in the effects of the two trade-wind systems on temperature is closely reflected in their effects on pressure. We may divide the stations considered into two groups, a southern group including Ponta Delgada, Valencia, Paris, Berlin, and Bergen, and a northern group including Jacobshavn, Stykkisholm, and Vardo. The average coefficients of correlation of trade-wind velocities with subsequent pressure are shown by the broken lines in Figure 1, the scale for the northern group being reversed so that negative coefficients appear above the positive. The SE. trade is here represented by the direct correlations of Table 5. (Not reproduced.) The correlation coefficients between the trade-wind velocities and the sea-surface temperature are shown by the continuous lines. The correlation coefficients of the trade winds with pressures at the southern group show good agreement with those of the trade winds with sea temperature, in spite of the difference in the periods utilized; those with pressure at the northern group (reversed) show a similar but not so close agreement.

A tendency also appears for the curves representing the northern group to lag behind those representing the southern group.

There is a well-known opposition between pressure in the Azores anticyclone and its northeastward extension and pressure in the Baffin Bay-Iceland-Norway coast depression, and this opposition would tend to appear in any correlation coefficients between some third variant and these pressures.

Figure 1 shows that powerful trade winds cause high temperature over the North Atlantic after an interval of 12 months for the NE.

trade and 15 to 21 months for the SE. trade, and that this high surface temperature in some way brings about a high barometric pressure over the southern part of the region and a low pressure in the northern part, so that a high surface temperature in the North Atlantic gives rise to an abnormally steep barometric gradient from south to north.

Space does not permit touching upon the many phases of the subject considered. Ten major conclusions are presented as follows:

(1) The surface temperature of the North Atlantic Ocean between Florida and Valencia has a positive correlation with synchronous pressure over the area Valencia, Bergen, Berlin, and Azores, but a negative correlation with pressure at Jacobshavn and Stykkisholm.

(2) The pressure at Jacobshavn and Stykkisholm has a positive correlation with the NE. trade wind four months before, this relationship not being due to the influence of the Gulf Stream.

(3) The surface temperature of the North Atlantic has a positive correlation with the NE. trade wind 12 months before, this relationship being due to the influence of the Gulf Stream.

(4) The surface temperature has a negative correlation with the NE. trade wind 15 to 21 months before.

(5) The correlation between the pressure in western Europe and the North Atlantic and the strength of the NE. trade wind 12 to 21 months before is generally small, but the coefficients usually have the signs to be expected from relationships (1), (3), and (4); that is, pressure at stations in the area Valencia, Bergen, Berlin, and Azores tends to have a positive correlation with the NE. trade wind 12 months before, and a negative correlation with the trade wind 15 to 21 months before.

(6) The surface temperature of the North Atlantic has a positive correlation with the velocity of the SE. trade wind 15 to 21 months before, this relationship being due to the influence of the Gulf Stream.

(7) Pressure at Valencia, Paris, Berlin, and Ponta Delgada has a positive correlation with the velocity of the SE. trade wind 15 to 21 months before; pressure at Jacobshavn, Stykkisholm, and Vardo has a negative correlation with the velocity of the SE. trade wind 15 to 21 months before.

(8) The surface temperature of the North Atlantic and the pressure at Ponta Delgada have a positive correlation with the Bermuda-Charleston pressure difference 3 to 9 months before and 15 to 18 months before.

(9) The surface temperature of the North Atlantic has a positive correlation with the Bermuda-Sydney (Nova Scotia) pressure difference three months before; the pressure at Ponta Delgada has a small positive correlation, and pressure at Jacobshavn a small negative correlation with the Bermuda-Sydney pressure difference three months before.

(10) The pressure in Western Europe and the North Atlantic (except the Azores) has a negative correlation with the pressure difference three months before between the point 50° N., 20° W. and Vestmanno, Iceland. At the Azores the correlation is positive. —*A. J. H.*

IMPROVED WATER-FLOW PYRHELIOMETER

By W. M. SHULGIN, Scientific Collaborator and Lecturer

[Timiriaseff's Academy of Rural Economy, Moscow, U. S. S. R.]

Doctor Abbot in America has constructed a water-flow pyrheliometer, which appears to be the most accurate standard apparatus for the measurement of the intensity of solar radiation yet made. My work at the meteorological observatory of the Timiariaseff's Academy of Rural Economy, Moscow, has for its object the continuation of these studies of the pyrheliometer for the purpose of improving its construction and increasing its accuracy. I describe here a method that permits the intensity of solar radiation to be measured with an accuracy of 0.1 per cent or more, depending upon the sensitiveness of the galvanometer.

The theory of the apparatus constructed by Doctor Abbot, and described in the Annals of the Astrophyical Observatory of the Smithsonian Institution, Volume III, is quite simple. In order to attain high precision a flow of water at constant temperature at all points is indispensable. For this purpose there is required a thermostat which will allow only insignificant fluctuations of temperature, not exceeding 0.0001°. This thermostat should be located as near as possible to the entrance to the pyrheliometer, and then care must be taken that the water that passes it does not change temperature before reaching the calorimeter.

Numerous experiments convinced me that in the case of an open platform and an inserted tube such a thermostat is impracticable. I have therefore planned an improvement of the apparatus itself that will obviate the necessity of constant temperature of the flowing water.

I have investigated the necessity of constant temperature of the water during considerable periods and the objections to fluctuations in temperature.

I have reached the conclusion that under certain conditions variations in temperature of the water do not interfere with the accuracy of the apparatus.

Let us suppose that first of all we have obtained a constant temperature of the flowing water. Then the readings of our two thermoelements, one at the ingress and the other at the egress, will be zero. But suddenly a column of hot water appears at the ingress. (Fig. 1.) As soon as it reaches the ingress thermoelement the latter will receive a temperature increase of t_2-t_1, and the galvanometer will record t_2-t_1 (fig. 2) until the hot column leaves the ingress thermoelement. In Figure 3 it has nearly left it; in Figure 4 it is entirely separated from the ingress thermoelement, and the galvanometer again reads zero.

As it advances the hot-water column reaches the egress thermoelement, Figure 5, and the galvanometer is deflected by a current of the same strength as before, but having the opposite sign. The galvanometer again comes to the zero line when the hot-water column leaves the egress thermoelement, Figures 6 and 7.

The phenomena of the passage of a hot column in an ideal case (absence of inertia in the galvanometer, no loss of heat from the water column, etc.) are reproduced in the lines of Figure 8. During half a minute, the time required for the water column to traverse the tube, the recording galvanometer has inscribed two quite similar squares, but of opposite sign, the algebraic sum of the areas of which equals zero.

Actually we have no water columns with such sudden transitions from high to low temperature. The thing to be noted is that if the hot columns follow one another regularly and their temperatures are equal, then the sum of the squares recorded on the photogram and the sum of the heat received by the calorimeter during the half-minute interval are each equal to zero.

It can even happen that the hot columns will pass the thermoelements synchronously. Then the galvanometer will record a continuous straight line, without arches or depressions, notwithstanding the variations in the temperature of the water flow. Let us indicate the length of the spiral tube of the apparatus by L, the length of the cold column by l_1, the length of the hot column by l_2. Then evidently synchronism will obtain when $\frac{L}{l_1+l_2}=$ a whole number. Therefore regular variations in the tem-