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and for five months, owing to the perils of the Rotang Pass, the valley rarely has any communication with the lower world.

So fascinating is Kylang that I camped there for three weeks, till the harvest was brought home with joy and revelry, and the flush of autumn faded, and the first snows of winter gave an added majesty to the glorious valley. I spent five weeks on the descent to the Panjāb, journeying through Upper Kulu, and the interesting native States of Mandi, Sukket, Bilaspur, and Baghat, and early in November reached the amenities and restraints of the civilisation of Simla *en route* for Persia and Khurdistan.

A NEW CHART OF THE CURRENTS OF THE NORTH ATLANTIC.

(*Read at Meeting of British Association*, 1892.)

By H.S.H. Albert, Prince of Monaco.

(*With a Chart.*)

During the years 1885, 1886, and 1887, I made several series of experiments upon the superficial currents of the Atlantic in my sailing yacht *Hirondelle*. In 1885, as a preliminary trial, 169 floats were launched at intervals along a line 170 miles long, in the direction of N. 14° W., from a point situated 110 miles NW. from Corvo, one of the Azores. These floats were of three different types—wooden casks, copper globes, and glass bottles. They were all weighted in a manner to prevent any part of their bulk emerging from the water and catching the wind. This first experiment having given some useful results, a further experiment was made on a larger scale in the following year. On that occasion 510 floats were launched at intervals along a line nearly on the meridian of 17° 40′ west of Greenwich, 510 miles long, between 42° 34′ and 50° N. latitude. The object aimed at by these experiments having been largely attained, I made a third and much more extended set of observations during the year 1887. This time 931 floats of thick glass, covered with copper, with an intermediate coat of pitch, were launched along a line extending from the Azores to the Grand Banks of Newfoundland. On returning from this voyage, a little group of floats was again launched on a length of 128 miles between the two following points, viz., lat. 49° 31′ N., long. 29° 7′ W.; and lat. 48° 58′ N., long. 26° 7′ W. Each float contained a document printed in nine languages, which invited anybody who might find one of the floats to deliver it into the hands of the nearest maritime authorities, to be sent to me with detailed indications of the place and date of finding it.

Of the floats which had been thus launched in four different parts of the North Atlantic, 227 were sent back to me, and I have carefully studied their history. This has furnished me with valuable indications, not only of the direction, but also of the speed of the current, and I have already laid successively several accounts of them before the Academy of

Sciences in Paris, which has published them in the *Comptes Rendus*. Finally, at the commencement of the present year I published a chart of the currents of the North Atlantic, entirely based upon the results of these experiments.

The following table shows how the floats were distributed upon the coasts washed by the Atlantic:—Azores, 37; Madeira, 6; Canaries, 21; Iceland, 3; Norway, 22; British Islands, 29; France (West), 36; Spain (North), 14; Africa (West), 7; Antilles, 23; Central America, 1; Bermuda, 4; open sea, 3; various, 5. The study of these facts furnishes us with the following information upon the direction and speed of superficial currents.

Velocity of Current.—In order, in a general way, to arrive at the velocity of the current, I have divided the vortex traced out by the floats into sections, the limits of which are, first, the lines of origin of the different series of experiments, and the coasts where the first floats of the same series of experiments have appeared in groups, and within a short interval of time; then these coasts, and certain points of the coasts following, on which floats having the same origin have stranded successively in the order in which they have been launched.

Direction of the Current.—In 1889 I pointed out that the recovery of two floats in the open sea, south-west of the Azores, a very few weeks after they had been thrown overboard to the north-west of these islands, demonstrated that the internal edge of the great vortex, traced out by the whole of the floats, performs a revolution with a very short radius round a point to the SW. of the Azores, and not very distant from them. Just as in an atmospheric cyclone, there exists in this oceanic vortex a region of calm, where the waters do not follow any regular direction, and when the floats enter this region they remain there often for months or years.

The stranding of floats successively on the Azores, on the coasts of Europe, Africa, Central America, the West Indies and Bermuda in the course of a normal period; then the repetition of this same circuit, indicated by the 4 floats recovered in 1891 (2 on the coast of France, after being afloat for 4 years 3 months and 5 years 3 months respectively; and 2 on Madeira, after a voyage of 3 years 11 months and 4 years 2 months respectively) enables us to establish the fact that the cycle, described by the objects drawn into the vortex of the waters of the North Atlantic, is renewed indefinitely, except in the case where they escape by an off-shoot into the Arctic regions along the coasts of Ireland, Scotland, and Scandinavia. This conclusion is arrived at by comparing the dates of the launch and recovery of these 4 floats, and applying to them the mean velocities deduced from the voyages of the earlier floats, as set forth in a table.

The indications which I thus obtain by following the floats from one station to another, round the Atlantic, are sufficiently good to permit me to offer figures which must be approximately exact.

The unpublished table which summarises these facts shows:—

1. The geographical and annual distribution of all the floats recovered. 2. The mean velocity of the first floats, recovered from

each series of experiments. 3. The number of floats used for the establishment of these means; and, 4. The total number of floats recovered in each district, and from each series of experiments.

In each section a certain number of the floats recovered has been rejected, because their late appearance indicated accidental retardations of unknown duration at one or more points of their course.

In some cases, a single float belonging to one series of experiments is accepted as furnishing the mean of a section, because the rate which it indicates does not differ materially from the mean rate deduced from the two other series of experiments for the same section.

The velocities which may be accounted most accurate are those furnished by floats recovered on thickly populated coasts, because they are sure to be secured without much delay, either being entangled in fishermen's nets, or picked up by boats or by persons on shore. And in fact it is on such coasts that we observe the smallest amount of variation in the velocities of the floats which have appeared, and for the same reason a greater number of them are available for the deduction of means. This is the case for the coasts of Madeira and the Canaries, which are always surrounded by fishing boats; for those of Portugal and Spain as well as for Ireland and Scotland. The same remark is applicable to the coasts of Morocco as far south as the Sahara, but here it is due to the custom of the miserable tribes of the country who continually visit their extensive beaches in search of wreckage.

In the West Indies and in Norway the great extent of the coast-line, as compared with the population, produces a contrary effect. The three floats recovered from Iceland have not been utilised, because the scarcity of population is still greater there.

I cannot utilise for the determination of the mean velocities the four floats recovered in Bermuda whose voyages have lasted years; but, taken along with those picked up in the open sea to the west of the Azores, they have aided me in recognising the inner border of the oceanic vortex, and have helped me to understand why many floats which have disappeared for a long time have afterwards appeared near to these same Azores, and even, although more rarely, in Europe.

Floats which have been exceptionally long at sea have been excluded from participation in the establishment of means. On the other hand I have applied to them the general mean velocity found from the whole of the sections, and I have laid down on the chart their courses, by lines drawn parallel to the curve of general circulation and connecting their points of origin and of recovery, and of a length given by the mean velocity multiplied by the number of days that they were afloat.

The mean velocity for the region comprised between the Azores, Ireland, and Norway is 3·97 nautical miles in twenty-four hours; between the Azores, France, Portugal, and the Canaries it is 5·18 nautical miles in twenty-four hours. From the Canaries to the West Indies, the Bahamas, and even to Bermuda it attains 10·11 nautical miles in twenty-four hours. In the eastern portion of the arc which extends from Bermuda to the Azores it falls again to 6·42 nautical miles in twenty-four hours. The mean velocity which the combined results give for the North Atlantic is 4·48 nautical miles in twenty-four hours.

It is apparent that circulation is more active on the western half-circle of the vortex than on the eastern one; and this is explained by the combined action of various causes, as the trade-winds, the equatorial currents, and the Gulf Stream, also the powerful evaporation which in the Tropics stimulates the circulation of the waters, as by the increase of density it always tends to re-establish equilibrium. It would now be of great importance to renew these experiments at different seasons.

METEOROLOGICAL OBSERVATORIES IN THE ATLANTIC OCEAN.

(*Read at Meeting of British Association*, 1892.)

By H.S.H. Albert, Prince of Monaco.

Attentive observation of the progress made by Meteorology in the last fifty years, along with the reflections suggested by my own work in the field of Oceanography, have led me to conceive a plan which, if carried out, will, I feel convinced, have a very great effect in furthering the advancement of these sister sciences.

Maury's researches on the laws of the winds furnished information of so practical a nature regarding the best track for sailing ships, that navigators were able at once to save half of the time that had been formerly required to make the passage from the United States to the Equator. Since then, and principally owing to the labours of Fitzroy, Leverrier and others, a network of observatories, which now covers all Europe, has been developed, and informs us of the simultaneous variations in the state of the atmosphere, thus enabling us to advance a certain distance in forecasting the weather. Similar observations, collected at the Weather Bureau in Washington, enable us at times to be warned of great atmospheric disturbances advancing towards us. Information, collected by the same office, from the multitude of ships which enter the ports of the United States, enables it to publish each month a *Pilot Chart*, of the greatest interest alike to mariners and meteorologists, which gives the position of the icebergs, cyclones, and wrecks met with at sea during the preceding month. It does not, however, confine itself to recording past events. By the skilful use of the large amount of material brought together, it indicates for the current month the probable limits of the fogs in certain regions of the Atlantic, and of the ice in the neighbourhood of the North American coasts; it shows also the probable direction of the winds on the whole Atlantic.

But the Atlantic is too vast a region for it to be possible to predicate what is going on in its centre from observations made on its borders; and observations made at sea, which sailors bring home, often arrive too late to be of use for forecasting. We are therefore at present very imperfectly warned of what the sea is preparing for us.

If we consider this question more closely, remembering how great