ART. XX.—ON THE TEMPERATURE OF THE SURFACE WATER OVER THE BANKS, AND NEAR THE SHORES OF THE GULF OF ST. LAWRENCE ; BY WILLIAM KELLY, M. D.

[Read 5th March, 1836.]

The temperature of the ocean is known to vary in particular situations, independent of the changes that result from difference of latitude. The most striking instance, perhaps, of these varieties in the temperature of the surface, is that observed in passing from the Gulf stream, to the neighboring banks of Newfoundland. Differences of the same kind, but less in degree, have been observed in other situations. Thus, Baron Humboldt, Doctor Davy, and other travellers, who paid particular attention to the temperature of the surface of the ocean, have observed, that, in most instances, it suffered a marked diminution when they were passing over banks, or approaching land. During the process of the survey of the Gulf of St. Lawrence, we have had frequent opportunities of making similar observations, and for the most part, with similar results. Whenever we had occasion to observe the temperature of the surface over banks or shoals, away from the land, we found it always less than where the water was deep ; but, in approaching land from the centre of the Gulf, though we generally found the surface colder, yet it was not invariably so ; and, in some cases, it was warmer near the land, than at a distance from it. In harbors, also, a great variety of temperature was observed—the water being one day comparatively warm; on the next, perhaps, intensely cold. I shall endeavor to point out the circumstances that accompanied and seemed to influence these changes, as far as they came under my notice, with the hope of throwing some light on the general question ;—for, as the Gulf is a sea on a small scale, a knowledge of the causes which influence the temperature of its surface, can scarcely fail to be of use in any enquiry that is made into the causes of the variations of temperature in similar positions in the ocean.

On a former occasion, I laid before the society some remarks on the temperature of the water of the estuary and adjoining parts of the gulf, which have since appeared in the TRANSACTIONS. It was shown, that the great mass of the water there, was cold ; and that the upper stratum of warmer water, usually observed,

was of inconsiderable depth; that it was never seen in some situations, and ceased to be distinguished in any part of the estuary, when the water was much agitated. In the Gulf, I found, that, although the main body of the water was cold, as in the estuary, yet the upper stratum of warm water was of greater depth; and hence, the temperature of the surface in the gulf was not so much, nor so readily reduced by agitation, as in the estuary. The temperature of the water was not found to decrease regularly, in proportion to the depth, in either situation. On one occasion, the water, brought from a depth of 20 fathoms, was warmer than what was brought from 10, or from 47 fathoms; and, in every instance, we found it warmer at 100 fathoms depth, than at 50. When, however, portions of water, drawn from different depths, were examined by the hydrometer, the specific gravity was always found to be greater in those which came from greater depths—the saline contents of the strata thus giving them a relative position different, in some instances, from that which they would occupy, if their specific gravities were influenced by their temperature alone.

If we suppose, in accordance with our observations, the waters of the Gulf of St. Lawrence to be divided into strata of different temperatures, the position of these strata will bear a striking analogy to what the geologist observes in some great secondary basins, where a stratum that lies deep towards the centre, often crops out at the surface, all round its edges.

The varieties in the temperature of the surface water, near the shore, seem to be owing to three causes: 1st,—The banks, shoals, and rocks, which resist the currents arising from tides, or other currents that affect the whole mass of the water; 2nd,—The rivers that open on the coast; and, 3rd,—The winds.

When the lower cold strata of water have their course retarded by the obstacles mentioned in the first case, and advance more slowly, in consequence of the friction against the opposing body, the strata next above, retaining their original velocity, have a tendency to rise over the obstruction, and thus to attain a higher level than they previously occupied. When the obstruction is small, the current weak, or the upper warm stratum of considerable depth, no perceptible effect on the surface ensues; but, in contrary circumstances, the lower strata are brought to the surface, the result of which is a considerable diminution of its temperature. In this way, the cold ordinarily observed over banks, and near shores, may, I think, be explained. *

* The difference of velocities, resulting from inequalities of the bottom, is

In the Gulf, we always find the water of the rivers warmer than the sea. As the fresh water, from its inferior specific gravity, has a tendency to float on the surface of the salt, whenever a large river, or several small ones, enter the sea, they tend to make the surface warmer than in other situations.

The influence of the winds is two-fold. The agitation they produce, by mixing all the strata, tends materially to cool the surface; but their direction seems also to have a considerable effect on the water near the shore, especially when combined with other causes. When they blow on the land, without sufficient force to mingle completely the surface water with the colder water beneath, they tend to propel the warmer surface water of the central parts of the gulf, nearer to, or on the coast, and to keep the water of the rivers also close to it. When the winds are off the land, they prevent the water of the rivers from acumulating near it, and force the warm surface water of the central parts further from the shore.*

In the paper already alluded to, I attributed the effect of the winds on the surface, solely to the agitation they produced; and such seemed to be the legitimate result of our observations up to that time; but, along the coast of Labrador, I found their effect in cooling the surface, to be, in many instances, unconnected with their power of agitating the sea in the immediate vicinty. The easterly sea winds, which most readily reduce the temperature of the surface in the estuary, are generally accompanied here by an increase of its temperature; and the water is coldest during the prevalence of westerly winds, particularly when, by having some northing, they come direct off the land. These changes of temperature in the water, have no relation to the temperature of the air at the time,—as during summer, the winds from the land are warm, and those from the sea, cold.

Winds off the land are generally drier than sea breezes—hence their passage over the surface of the water is attended with much greater evaporation from it;—perhaps this is another reason why the surface is colder with winds off the land.

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probably the cause of the whirls and eddies which we often see when the tide is strong. These whirls and eddies mingle the surface and deep water completely. The interruption to currents, caused by a strait or narrowing of the shores, seems also to have a similar effect. We found the greatest cold in the surface water at the strait of Belleisle, at Mingan, and Point de Monts, where the width is considerably diminished; and near Bic, where the river becomes narrow and shoal at the same time.

* Some years ago, I was in the habit of bathing at the head of a bay on the west coast of Ireland, and remember well that the water was always warm when it was much agitated by westererly winds; whilst it was often

The effect of land and sea winds on the surface water, is more remarkable in the harbors immediately on the main, such as Mingan and Kegashka, than in those which are formed by islands some distance from it, as Wapitiguu.*

In the strait of Belleisle, we found the water warmer on the Newfoundland side, than on the Labrador shore. The only circumstance that seemed to account for this, was, the evidently greater strength of the tides on the Labrador side. As the temperature of the water on the Newfoundland side corresponds very nearly with that observed at a distance from the shore, in the neighboring part of the Gulf, it seems probable that a slight current outward may exist on this side,—being a kind of eddy to the usual current in, which is so evident on the other. No large rivers empty themselves on this part of the Newfoundland coast.

The remarks on the temperature of the water at different depths, were reduced from the following observations :—On the 19th of June, 1832, off Point de Monts, the water at the surface was 43° ; at the depth of 10 fathoms, 37°. 5 ; at 20 fathoms, 39° ; at 47 fathoms, 33° ; at 104 fathoms, 36°. The increase of temperature between the depths of 10 and 47 fathoms, made us suspect the accuracy of the result on the first trial ; but a second one confirmed it. The specific gravities, however, increased regularly —being 1:019, 1:023, 1:0246, 1:026, and 1:0275. At the same place, on the 9th of July, 1831, the temperature of the surface was 57° ; at a depth of 4 fathoms, 40° ; at 10 fathoms, 38° ; at 100 fathoms, 35°. The specific gravity at the surface, was 1:017—increasing to the greatest depth, where it was 1:0275. On the previous day, the temperature of the surface off Matane, (some miles higher up the estuary,) was 54° ; at a depth of 50 fathoms, 34°. In the Gulf, several miles off the north shore of Anticosti, the surface water on the 10th of August, was 54° ; at a depth of 10 fathoms, 46° ; at 30 fathoms, 34°. 5 ; at 50 fathoms, 34° ; and at 100 fathoms, 37°. The specific gravities were in accordance with the depth—increasing from 1.0225, at the surface, to 1.027 at the greatest depth. In Min-

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very cold in calms, or with winds off the land. But, as this was a matter of feeling, not measurement, it cannot go for much. I was, however, forcibly reminded of it by my observations on the Labrador coast.

* This harbor is on the outside of a labyrinth of rocks and small islands, that line the coast for several leagues, in both directions. The warm water of the rivers of the main must accumulate, in some degree, within these islands, on ordinary occasions ; and the first effect of land winds would only be, to propel it towards the harbor on the outside.

gan harbor, on the 2nd of September, 1832, at 10 A. M., the water of the surface was 53°; whilst at the depth of 10 inches, (the length of the thermometer,) it was only 47°.*

We had a remarkable instance of the coldness of the water over shoals or banks on the 29th June, 1832. We found the temperature of the surface only 33°, in passing over a shoal ledge, that runs out to a considerable distance from the Mingan Island, and, by its situation, must obstruct the course of the tides, between the northern parts of the gulf and the estuary. On the previous days we found the water in the estuary 47° or 48°. It was nearly calm as we passed the ledge, but there was a considerable swell.

The most remarkable changes in the temperature of the water in a harbour occurred, as I have already mentioned, in Kegashka; where we lay at anchor from the 15th to the 30th August, 1832. This is a small harbour on the Labrador coast: the entrance is narrow, and divided into two channels by a small rocky island. It stretches to a comparatively great length within, in the line of the coast: but the chief part of this extent is shoal. The coast outside, both to the E. and W. is broken by numerous rocks, many of which lie some miles from the main. There is no river in the harbour, but rivers and streams are numerous along the coast. On the 14th August, at 9 A. M, the temperature of the surface water, some leagues from the land, was 53°, the air 54°, winds light and variable. On the 15th, in Kegashka, at the same hour, the air was 56°, thewater 48°. There was a dense fog on the surface: it had been calm all night, but there was a considerable swell. On the 18th after two days of fresh westerly winds, blowing along, and rather off

* As the depth of water in the places where these examinations were made, was little more than 100 fathoms, it seemed probable that the increase of temperature at that depth might have been owing to that derived from the bottom itself, which would probably have the same temperature as the mean of the earth ashore (about40°), I was consequently desirous of making a trial where the total depth was much greater. On the 17th of June, 1836, we were becalmed about 12 miles S. E. of Point des Monts. The temperature of the surface was 51°—specific gravity, 1.0180; at a depth of five fathoms, temperature 42°5; at 10 fathoms, temperature 38°; at 30 fathoms, temperature 32°5—specific gravity, 1,0261; at 50 fathoms, temperature 33°—specific gravity, 1,0266; at 80 fathoms, temperature 34°—specific gravity, 1,0266; at 110 fathoms, temperature 35°—specific gravity, 1,0271; at 150 fathoms, temperature 35°—specific gravity, 1.0278. The specific gravities were ascertained in each case where the water had acquired a temperature of 50°. It was evident here that the increase of temperature at the depth of 100 fathoms, was unconnected with the temperature of the bottom; but we may remark, that, though the temperature of the water did not alter below this depth, yet the specific gravity continued to increase.

the land, the temperature of the surface fell to 38°. From the 18th to the 28th it fluctuated between 38° and 52°, as the winds were more or less fresh, off or on the shore. On the 28th a south wind blew directly on the shore. The water rose to 55° that evening, and varied between this point, and 52° for the two following days; the wind being light, shifting a little to the eastward, and blowing directly on the coast.

Off Mingan harbour, on the 31st, the surface water was 51°, the air 56°; on that night there was a very fresh wind from the northward, and on the morning of the 1st September, the water in the harbour was 39°, the air 52°. Mingan harbour is formed by an island lying parallel with the coast; a considerable river empties itself into the eastern end of it; the temperature of the water of the river on that day was 51°.*

On the 6th of August 1832, the water in the offing was 51°, the air 55°: near the shore, soon after, we found the water 55°; the temperature of the air had fallen in the mean time to 53°. This was at Nabisippi, where a river empties itself on the open coast.

The difference of the temperature of the water near the shore, from that in the offing, was observed also on the south coast. On the 10th October, near Cape Gaspé, the surface was 41°; at some distance out, 43°. On the 11th, at 9 A. M, the surface water, near Mount Louis, was 41°, air 48°: at 10 we had got out about 7 miles, with a fresh breeze from the westward; the surface was 47°, the air 52°.

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*On the 12th October, in the bay of Seven Islands, at 9 A. M, the air was 50°, the water 46°, on the 13th the air 44°, the water 42°, on the 14th both air and water 39°. There had been fresh breezes off the land during the three days. Two rivers of moderate size empty themselves into this bay.