TRANSACTIONS.

ART. I.—ON THE TEMPERATURE, FOGS AND *MIRAGES* OF THE RIVER ST. LAWRENCE. BY WILLIAM KELLY, M. D. SURGEON, R. N.

READ BEFORE THE SOCIETY ON THE 4TH FEBRUARY, 1832.

THE naval surveying party employed on the St. Lawrence, under the command of Captain Bayfield, leaves Quebec every year towards the end of May; and returns at the close of the month of October. The intervening time is passed in different parts of the river and gulf. During the progress of the survey in the years 1829, 30 and 31, frequent opportunities occurred for making the observations, now submitted to the Society.

The temperature of the waters of the St. Lawrence differs very much, as might be expected, in the different seasons. But as the changes of temperature in the water are gradual and slow, whilst those of the air, both at the approach of summer and winter, are very sudden and considerable, certain atmospheric phenomena result, the endeavour to account for which is the chief object of the present paper.

On collecting the observations, however, respecting the temperature of the surface water, it appears that it does not uniformly follow the changes of the seasons; but is

much influenced by certain localities, and by the strength and direction of the winds. Where free from these disturbing causes, the water acquires its maximum temperature about the beginning of September. The mean maximum temperature of the air is in July.

Above the Richelieu, the river, little influenced by the tides, warms or cools as the seasons change. It sinks to 32° when the river is frozen over in the winter, and rises to 62° by the beginning of September. The temperature of 62° I found constant both at the surface and in the deep water all the way from Crane Island to Lake St. Peter, whilst making a passage up the river in September, 1831; and from Quebec upwards in 1830, though the average temperature of the air, at the time, was only 56°.

In the tide waters above Red Island, especially in the south channel where the depth is much less, and there is a much greater proportion of fresh water than in the north, the temperature at the surface increases with tolerable regularity during the summer, though suffering a temporary reduction from time to time in consequence of easterly gales. As we generally anchored on the south side during the two last summers, I have not had an opportunity of ascertaining the temperature of the waters in the north channel, but from the complaints made by the bathers at Malbaye of the coldness of the water, the influence of the summer's heat on it would seem to be much less than on the south shore.

But below Red Island, where the river expands into an æstuary, this influence is only perceptible in fine weather, and is even there confined to the surface. On the morning of the 8th July, 1831, after some days of warm clear weather and light winds, the surface water about half way between Matane and the north shore was 60°. A fresh breeze from

the westward came on in the evening, and continued all night; on the morning of the 9th the surface water had fallen to 39°. The temperature of the air at this time was between 64° and 62°. It fell nearly calm again towards mid-day, and the temperature of the surface rose to 57°, but again blowing with increased force during the night, on the 10th, at 9, A.M. it had fallen to 37°, and the air to 44°.

On the 8th, when the surface water was at 60°, water taken up by Dr. Woolaston's machine from a depth of thirty fathoms was 35°, from fifty fathoms 34°. During the calm on the 9th, off Point des Monts, the temperature of the water at different depths was found as follows. Surface water drawn up in a bucket (care being taken to prevent its being influenced by the temperature of the vessel,) 57°. The register thermometer sunk three feet indicated 44°, at ten fathoms 38°, water drawn from a depth of 100 fathoms 35°. The specific gravities of these waters also differed very much. On the 8th, the surface water was 1,0180; that from thirty fathoms 1,0260, that from fifty fathoms 1,0265. The water taken up from 100 fathoms on the following day, had a specific gravity of 1,0275.

Hence it appears, that in fine weather the warm fresh water of the river and tributary streams floats on the surface; but when the waters are agitated, it becomes mingled with the permanently cold waters beneath. The temperature of the surface water, therefore, depends more on the strength than the temperature of the winds. In the higher parts of the river their direction also has great influence; as the easterly gales, by causing a commotion in the deep waters all the way from the gulf, tend much more to cooling the surface, than the westerly, which only act on a comparatively small extent and depth; and besides on

parts where there is a much greater proportional admixture of fresh and warm water.

Besides these causes, more or less temporary, of difference of temperature on the surface, arising from the seasons and winds, there is another, which seems to operate constantly between Red Island and Bic inclusive. It may, perhaps, extend farther down on the south shore, and up on the north, but we have had as yet no opportunity of ascertaining it. We made repeated trials of the temperature of the surface water within this space, and never found it to reach 50°. It was usually from 38° to 45°. It was the same in June, July and September, and probably in August, though we had no opportunity of trying. Its specific gravity was also much greater than that of the surface water lower down in fine weather.

Between Red Island and Bic there is a constant set down, *much greater during the flood tide, in some parts*, than in the ebb. This latter circumstance, combined with its greater coldness and specific gravity, corresponding with the deep waters, would seem to indicate that the lower part of the great tidal wave, meeting with a sudden resistance, was forced to the surface, and at the same time compelled in part to take a retrogade course. A reference to a correct chart will shew that such resistance exists in consequence of the change in the form of the bottom at this place. The south bank, increasing in breadth from Matane to Bic, causes the mass of the tide water to flow along the north shore; whilst Bic, and Bicquette projecting across the course of the water that flows on the bank, it cannot arrive so speedily at the space above these Islands, as the principal tidal wave. But this wave is itself also checked, first, by Red Island and its extensive shoals; and again by the *com-*

paratively shoal bank, that extends from White Island to the south shore. The deep water meeting this resistance at Red Island, is consequently forced up, giving rise to the frightful eddies and whirls that surround it.* The interruption of its free course causes the water to attain a higher level at this place, and a part of it flows back past Basque and the Razades,and over the bank above Bic and Bicquette, where, as already mentioned, it must, from the obstruction caused by these islands, be slower in acquiring the general level of the mounting waters. Had the obstruction at Red Island not existed, it is probable that the tides above Bic would be the same as immediately to the eastward of it; that is, it would set on the bank, or towards the shore, at the first of the flood; and off the bank, or from the shore, at the beginning of the ebb, instead of flowing straight up and down, as it does in those parts where no banks or shoals exist.

The constant current down between Red Island and Bic, has been attributed to the flow of the fresh waters of the St. Lawrence and Saguenay; but how can this take place at the same moment that all the water above the former points, fresh and salt, is flowing rapidly upwards. Besides its increased rapidity during the flood tide, its coldness in all seasons, and above all, its specific gravity, are in direct contradiction to such an opinion.

The temperature of the deep water of the St. Lawrence

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* Are the fogs on the Banks of Newfoundland caused by the cold deep water flowing from the poles to the equator, being forced to the surface there in consequence of the interruption given by the Banks to its course to the southward? Humboldt found the surface water on the Great Bank 9° cent. lower than the surface of the neighbouring sea, and 12° cent. lower than the gulf stream, at no great distance.

has only been examined by us this year; but the extreme cold of the surface water in the space above mentioned, attracted our attention in July, 1829; and since that time we have found it the same, both in July and September, every year. At first we thought it might be owing to the presence of ice-bergs in the gulf; but being bound down at the time, and the weather being fine, we found the surface water,as we approached the gulph,become sensibly warmer, and no trace of ice-bergs there. We were afterwards disposed to attribute it to the waters of the Saguenay, which, entering here at an angle, seems to turn the stream of the St. Lawrence over to the southward during the ebb, and might be supposed, from its great depth, to form a reservoir of water remaining cold from the winter. But the facts since ascertained respecting the specific gravity of the surface water within this space, and the increased velocity with which it flows downwards during the flood tide, are irreconcilable with such an opinion. It is not difficult to understand why the deep waters of the St. Lawrence are cold at all seasons, when we recollect that there is a constant current through the Straits of Belle Isle into the gulf, which is probably a part of the great stream flowing from the pole to the equator; whilst the water of the river, from its inferior specific gravity, has a tendency to float on the surface, causing a constant current downwards along the south shore, as we approach the gulf, and not mingling generally with the salt water beneath, except when agitated by strong winds.

One of the most remarkable consequences of the coldness of the surface water, and the most important to those who navigate the river, is the fog, which, in fine weather with calms, or very light winds, often covers the surface of the

water. These fogs are sometimes so dense, that once at mid-day, whilst the sun was shining overhead, we could not see any part of a vessel, which passed so close to us that we could hear the people speaking to one another on board. They are not generally attended with rain; but the decks are often kept wet, and large drops fall upon the rigging, which seems to collect the condensed moisture of the atmosphere. Frequently by ascending some way up the rigging, we could look over the fog, and see the hills clear around us. Captain Bayfield remarked, that from a considerable height in the rigging, the view even towards the surface of the surrounding water was much more extensive than on deck.

On the 14th of June, 1831, between Red and Green Island, we passed through a fog that lay only on the water, the land being quite clear. The wind was moderate from the S. W. It had been blowing from the eastward for the three previous days. As we went along on a wind, a part of the surface to leeward and just astern of the vessel, was almost quite clear of fog. The clear part was in breadth little more than the length of our vessel; but its depth was considerable, and exactly in the direction of the wind. It preserved its relative situation just astern of the vessel as we passed down, and seemed to be owing to the vessel and sails preventing the breeze from coming in close contact with the water. Had we been stationary, it is probable the clear space would remain directly to leeward of us.

Whenever this fog occurred, the due point of the air ascertained by Daniell's hygrometer, was several degrees higher than the temperature of the surface water. If a fresh breeze sprang up, particularly from the westward, it was soon dispersed. It will easily be understood that

whilst air, with a high dew point, or, in other words, with much moisture, rested on the cold surface of the water; the latter, acting uninterruptedly on the same column, or stratum of air, would, by cooling it, cause much of its moisture to be precipitated; but if an equally moist wind blew briskly over it, no part of the air would be exposed to the cold from the water, for a length of time sufficient to cause a perceptible deposition. It was the great frequency of these fogs in the neighbourhood of Bic and Red Island, that first directed our attention to the temperature of the water at this place. Here they occurred with light airs, either easterly or westerly; but in other parts of the river, they were generally accompanied, or preceded by wind from the eastward. They occur in any part of the æstuary, when a calm follows quick on a fresh breeze in any direction, that agitates the waters, so as to bring the cold to the surface. Sometimes we observed such a fog lying on the waters of the north channel, whilst we were free from it in the south. This which may be distinguished as the fine weather fog is very different from that which usually accompanies an *easterly gale.* In the latter, the deposition seems independent of the temperature of the water, and appears to be caused by the mixture of currents of air differing in temperature and dryness. It extends into the upper regions of the atmosphere, cannot be overlooked from any part of the rigging of a ship, and is seldom so dense on the surface as to hide the view of objects within half a mile, or more, by day-light. It is generally accompanied by constant rain; and the sun is never seen to shine through it. It extends over land and water, the highest hills, as well as the low country.

A third species (if I may use the term) of fog, was noticed

at the head of Lake St. Peter, on the morning of the 30th September, 1831. It covered the river to a height of ten or twelve feet, and was hurried rapidly along by a strong wind from the westward. It continued from daylight until about 10, A. M. In this case, the circumstances were the reverse of what takes place in the Bic fogs, for the wind was very fresh, the temperature of the air 40°, its dew point 37°, the surface water 58°. Here the vapour, which was constantly escaping from the water, was instantly precipitated by the cold wind that passed rapidly over it. A similar phenomenon, on a smaller scale, is observed in winter, when a fresh wind below zero blows over an open space in the river. Do these facts militate against the opinion, that the water in the atmosphere is held in solution by the air? Can we suppose that it dissolves and precipitates it at the same time?

Another effect of the changes caused in the air, by its contact with the cold surface water, is the mirage which is seen occasionally, during the months of June and July, in every part of the river where the tide waters flow; and in the space between Bic and Red Island, at all seasons when we had occasion to visit it. It is always observed in fine weather, with a clear sky; and, like the fog first mentioned, generally in calms or light winds: but its presence seems compatible with a fresher breeze than I have ever known to accompany the fog. The remarks also respecting the direction of the winds, and the localities, apply equally in both cases. With this mirage, as with the fog, the temperature of the surface water has been invariably found lower than the dew point of the air; though the difference was generally much less in the former case, than in the latter. These circumstances seem to shew that both phenomena depend on the same

causes, varying only in degree. To this I may add, that I never saw the phenomena of the mirage to so great an extent, as occasionally at a moment when the fog was dispersing.

The first appearance generally noticed at the commencement of the mirage, is on the lower ridges of hills, or points of land that run into the water. Here a line of the trees with which all the hills are covered, seems raised much above the level of the rest, resembling precisely a straight lofty hedgerow; and the tops of all seem to attain the same level, however uneven the ridge may be on which they grow. The appearance of a hedgerow is soon lost, as all the trees attain the same apparent height; giving an appearance of an immense table, stretching from hill to hill. The shores in the meantime assume the appearance of a straight wall; and the islands seem girt with a similar enclosure, or bounded with precipices all round. Their tops also look flat like tables; and the small islands often assume a flower-pot shape, being expanded above, and seeming narrow at the base, near the water. In one instance, the islands of Bic and Bicquette seemed to join; the wooded tops appearing to meet, and leaving an arch beneath, through which the water of the narrow channel, that seperates them, seemed to flow. The spray on the beach sometimes seems to rise in foam to the tops of these imaginary cliffs; and the houses, and other objects on the shore, seem to attain a great height, and like the trees, almost all to reach the same elevation.

The appearance of the surrounding ships (for at this season there is almost always a great number passing up and down the St. Lawrence) is still more distorted. The appearances differ much; owing, apparently, to the ships being more or less remote. Sometimes, they appear to rise to

twice their usual height; whilst at others, the masts seem to reach to a few feet only above the deck. The more distant, in one case, was extended to a great height; whilst one nearer was so shortened, that I mistook it for the Halifax steam vessel, then expected from Quebec. Sometimes the upper sails seem double, a second set being seen at a considerable height above the vessel; and sometimes a second ship, hull, sails and all is seen above the first. In no instance, however, have I seen an appearance of inversion either in the upper or lower figure. Nor was the picture ever seen, without the vessel itself being visible at the same time. The houses and other objects on the land never seemed shortened, as the ships did occasionally; perhaps this was in consequence of their distance, as our vessel generally lay far from the shore.

There was generally with the mirage an appearance of a fog bank on the horizon, more particularly to the eastward; perhaps because the sea being open in that direction, the horizon was there better marked. The air within the horizon was at the same time perfectly clear. At times, instead of the bank, the horizon seemed only elevated; or there was an appearance of a double horizon. Sometimes of an evening this bank, or the elevated horizon, would reflect the light like a mirror. All these unusual appearances were generally lost on ascending the rigging from ten to thirty steps, when objects were seen in their natural shapes. The fog bank may perhaps be an exception, for I have never observed what effect ascending the rigging would have on its appearance; nor have we ever had an opportunity of ascertaining whether the fog really existed, or whether it might not be an appearance that would recede as we approached. Can it depend on the precipitation of

particles of water near the surface, so minute, as only to be visible at the horizon, where a much greater depth of them is in the line of vision? Would the presence of such minute particles of water in the atmosphere cause the peculiar refraction? From the change produced by the elevation of the spectator, it is possible that persons on the quarter-deck, or poop of a line-of-battle ship, or large frigate, being placed at a height so much above that of our surveying schooner, might pass some time in the St. Lawrence, at a favorable season for seeing this mirage, yet never witness its phenomena. On the 17th of August, 1831, near Manitou river, between Seven Islands and Mingan, during the mirage, which occurred in a calm with a considerable swell of the sea, the appearances presented by two small islands or rocks, at different distances from us, was very remarkable; for as the vessel rose on the wave, the more distant seemed to sink, and the nearer to be raised up; and again as the vessel sank, the first rose, and the near one was lowered. Even the different parts of the same island were variously affected, appearing to dance as the vessel rose and fell.

Sometimes the refraction was so great, that ships, passing or laying close to us, had a distorted appearance. In one case, the water seemed raised about a foot above its level, where it came in contact with a ship at anchor close by.

The mirage, which I have been endeavouring to describe, is seen chiefly in the early part of the summer, when the waters have not acquired a temperature approaching that of the air; but as the seasons advance, the air and surface water become in an opposite state. For now the water, draining off from the lands, warmed with the accumulated heat of the summer's sun, acquire a temperature greater than the average temperature of the air in the fall, and

consequently much above its dew point in clear weather. This state is also attended with a mirage, but it presents very different phenomena from those already described. The points of land, and distant trees, growing in low situations, seem raised above the horizon; but there is no evident alteration of their shape, nor of their relative elevation. The appearance of walls, precipices and table lands, so conspicuous in the former case, are never witnessed in this; but the horizon and sky seem interposed between you and distant objects, a phenomenon which is never observed in the other form of mirage. In fact, the whole of the phenomena, in this instance, seem to depend on the shortening or depression of the horizon; a circumstance which struck me particularly some years ago, in observing the Egyptian mirage, with which this latter, though of much less intensity, precisely corresponds.

Several travellers have noted the curious phenomena of the Egyptian mirage, the most remarkable of which is its assuming the appearance of a tranquil lake, in the midst of the desert. The deception is at first complete. The hills in the desert, and the trees and houses also, when it occurs in the cultivated parts, are seen elevated above its level, and reflected from its smooth surface, which extends in some directions as far as the sight can reach. But when, on looking at it attentively, you search for the line of the horizon, where the supposed water meets the sky, it is not to be found in the usual place. The hills, &c. are seen in the air; and tracing carefully from the more remote to the nearer points, you find that the horizon is really what you at first took for the near margin of a lake.

This connexion between the sky and the mirage could not be traced, perhaps, when the latter is observed, as

sometimes happens in a valley bounded by distant hills; as these interfering prevents our tracing the connexion. Neither would the irregular margin, which is caused by the unequal surface of the ground near the observer, readily suggest any idea of a horizon.

The part of the sky, in this case, placed between lofty objects and the shortened horizon is often very bright and shining; it then acts like a mirror, reflecting a picture, more or less perfect, of every object that rises above its surface. From this reflection, white houses on the shore sometimes seem lengthened, but the case differs altogether from the mirage first described; as the lengthening here is owing to the inverted image, whilst in the other there is only a simple elongation of the object, without any inverted picture.

Having heard (I think it was) the late Professor Playfair, in the year 1817 or 1818, account for the phenomena of the Egyptian mirage, by the diminished refracting power of the air at the surface, in consequence of its being rarified so much, by contact with the burning sand, as to become specifically lighter than the superincumbent stratum, I was at first satisfied that the principle could be applied to the mirage of the St. Lawrence; as the objects on the beaches and shore, under the influence of a hot sun, were the first that attracted my attention. But when I saw the ships also distorted, between which and me there was no heated surface, this explanation would not apply; and above all when I found that, on mounting some distance in the rigging, every object on the shore, even those much above my level, was seen in its natural shape, I became convinced that the cause of distortion did not exist on the land, but near the surface of the water: I examined the

temperature of the water, in order to try what inferences might be drawn from it, and finding it much colder than that of the air, I concluded that the unusual refraction, which certainly differed from the Egyptian mirage, depended on the stratum of air next the cold surface being cooled by the contact, and thereby rendered unduly heavier than that above it; and that the refraction depended on this disturbance of the usual arrangement. With this explanation, I rested satisfied for some time; but, as I kept a constant register of the temperature of the air, and a frequent one of that of the surface water, I was surprised occasionally to find the mirage appear, when the difference between these was not many degrees; whilst, at other times, under the apparently favourable circumstances of light winds and a clear sky, it did not appear, though the temperature of the water was considerably lower than that of the air. The second mode of accounting for the phenomena, was therefore nearly as unsatisfactory as the first.

During last summer, my attention was first directed to the connexion between the dew point of the air and the temperature of the surface water, in cases of mirage, by observing that the one just described, appeared to a very great extent immediately as the fine weather fog was dispersing.—(We had long before ascertained that this fog was caused by the air resting on, or slowly passing over a surface, whose temperature was below its dew point.) The appearance of a fog bank, that so often during this mirage seems to stretch across the horizon, with its equal elevation, which appeared to bear some relation to the table appearance of the distorted objects, gave strength to the opinion that both depended on the same cause; as did the fact, that in many cases both could be overlooked by

ascending to a height in the rigging. Numerous experiments made since that time, tend to confirm the opinion then formed. And on a reference to our meteorological journal for the previous years, in the few cases in which the mirage happened to be noted, as well as the temperature of the water, and dew point of the air on the same day, this relative state of both was invariably observed.

The second form of the mirage I first noticed, *particularly* at Mingan Harbour, at 11, A. M. on the 29th of August last, when I was surprised to find that the temperature of the surface water, though lower than that of the air, was higher than its dew point. The temperature of the air was 57°, its dew point 45°, the surface water 48° ; a very light air from the westward, oil barometer 30,52, (probably 15 or 20 higher than would be indicated by a good mercurial one.) I was a good deal perplexed with this at first, as my previous experiments on the mirage had shewn the relative state of the dew point and surface water to be quite the contrary ; and I repeated the experiment, to be certain whether there might not have been some mistake in ascertaining them, but the results were the same. I now remarked that the mirage itself exhibited totally different phenomena, from that I had previously been in the habit of observing. The distortion of form—the walled extremities —the flattened tops of the islands and headlands—the fog bank on the horizon, or double horizon, were all wanting. The shape of objects was not at all changed. The horizon, instead of seeming raised, was actually depressed ; a rock left bare by the ebb tide, at a distance of $3\frac{1}{2}$ miles, as well as an island 10 miles distant, seemed lifted into the air ; and the points of other nearer islands and head-lands had the same appearance. Every circumstance, in short, reminded

me forcibly of the mirage I had seen in Lower Egypt, in 1827. The following notes, on both forms of mirage, were made on the 30th, and following days, at the same place.

9, A. M.—The appearance of the rock, and outer (or distant) island, and the points of the near islands and main to the eastward, is the same as yesterday morning. All seem lifted up above the horizon. The portion of reflected sky between the inner islands and the vessel, resembles a perfectly smooth lake. Almost calm. Air 53°, dew point 49°, surface water 51°, oil barometer 30,59. As yesterday, there is no distortion of any of the objects; they are seen along the coast, with which the harbour island runs nearly parallel, the channel between them being very narrow, and receiving the waters brought down by the Mingan river. There is no mirage to the westward, where the sea is comparatively open. The mirage disappears on ascending a few steps of the rigging.

11, A. M.—The appearances continue the same. Air 60°, dew point 49°, surface water 53°, deep water (7 fathoms) 48°. A very light air from the westward.

0,30, P.M.—A breeze has sprung up, and the mirage has disappeared as far as it affected the rock and the land inside it. The rock seems now within the horizon, but the point of the near island, (7 miles distant) and the whole of the distant one, seem still raised above it.

1,45, P. M.—The wind has been gradually freshening, and the mirage disappearing in the same proportion; it was last perceptible at the outer point of the near island. Air 61°, dew point 49°, surface water 50°,5. Fresh breeze from the west ward—atmosphere clear.

At 3, P. M. on the 1st September, at the same place, we had the mirage with distortion of objects. It appeared first

to the eastward, and then to the westward, and did not last more than 15 or 20 minutes. The trees on the points took the hedge row appearance; the shores began to look walled; and one of the Paroquet islands assumed the appearance of a flower pot. Air 65°, dew point 59° 5′, surface water 56°, oil barometer 30° 45′, almost calm. A fresh breeze from the eastward sprung up towards night. A similar appearance had been observed to the eastward, only during a calm, on the morning before at 9 o'clock; it remained but a short time, and I had not then leisure to examine the temperature of the water, &c. A little before 10, after it had disappeared, the air was 61°, dew point 55°, surface water 54°. A very light air from the westward.

We left Mingan on the 6th of September, and I had again an opportunity of observing the mirage, with distortion, at Bic, on the 12th. The air was 48°, dew point 42°, surface water 40°.

On reaching Crane Island on the morning of the 16th, on our way to Lake St. Peter, the mirage, with shortened horizon, was observed on every side. We had now got into fresh water, with a temperature of 62°. The air at 9, A. M. was 50°, and did not, during the day, acquire the temperature of the water; the dew point was 40°. From this time forward, the mirage, with shortened horizon, was almost daily observed. The general temperature of the water, during the remainder of September, was 62°; the average temperature of the air at 9, A. M. 54°, the dew point 48°. There was no record kept of the heat of the air at any other time of the day; but I remarked that the mirage was most strongly marked, and the horizon shortest, during a calm on the warmest day that occurred in the month of September.

At anchor, near Isle Plat, on the 15th October, at 2, P.M. the air was 53°, dew point 37°, surface water 52°. A light breeze from the westward. The mirage, which had been very great during a calm, with cold air in the morning, (the temperature had been as low as 44°,) still continued, though in a less degree, the horizon having receded considerably. The same appearances were observed on the 16th: air at 9, A. M. 50°, surface water 53°, calm. At noon, air 54°, surface water 53°, a light breeze. When the mirage was less distinct in the warmer parts of these days, the examination of it was much facilitated by using a telescope; by the help of which, the line of the shortened horizon could always be readily traced. It also showed more distinctly the inverted picture of distant objects, formed by the reflected sky, between them and the shortened horizon.

Quebec, November 18, 1831, at 2, P. M. wind westerly, light, sky overcast, (the morning had been clear,) temperperature of the air 42°, surface water 42°,5. The mirage, with shortened horizon, was seen from the King's wharf between the island of Orleans and the main. On descending the steps to the surface of the water, a schooner between the near end of the island and the main seemed raised above the horizon. There was no opportunity of observing the dew point at the time, but it must have been much below the temperature of the surface, as there had been frost in the morning, and the thermometer fell to 33° again in the evening, without rain.

I noted this form of mirage, for the last time, from the King's wharf at Quebec, on the 27th November, at 1, P.M. The air, which had been 27° at 9, A. M. was now 30°, the surface water 38°, the wind fresh from the eastward, and the surface much agitated. The shortening of the horizon, and the apparent elevation of the points of distant land

were well marked. The houses on the near end of Orleans were reflected as in a mirror.

During the course of these observations, I was ignorant that any cause was assigned for the appearance of mirage, except great excess of the temperature of the surface, over that of the superincumbent stratum of air; I consequently neglected to record some observations of the occurrence of mirage with shortened horizon, when the temperature of the air was greater than that of the water. Neither did I, at that time, know that the shortening or depression of the horizon in this case, had been previously noted. It was, however, so remarkable a feature, that I distinguished this in my notes as the mirage with shortened or depressed horizon, whilst the other was designated the mirage with elevated horizon, on account of the contrast between them; or more generally the mirage with distortion, from the altered form of all the objects which were observed during its continuance. Finding, accidentally, that the subject had been discussed by Baron Humboldt, I referred to his work on my return from our cruize.

In the note D on the subject, in the 3d volume of his Personal Narrative, are many measurements, which shew satisfactorily that the horizon is really depressed, or shortened to a considerable extent; and that the different objects that seem lifted into the air, have also their apparent elevation changed, though in a much less degree. Contrary to what they appear, they are depressed instead of being raised, the angle with the zenith being increased. In summoning up the results of his observations, he says, "The oscillations of the horizon were 7′ 57″; those of the summit of Picuita* 2′ 25″; those of the summit of Boracha† 0′ 27″.

* A small island. † Another small island.

The usual depression of the horizon, independent of any refraction, ought to be 5′ 29″ ; I found it between 6′ 10″ and 14′17″." Having ascertained that near the equator the surface of the sea is 1° or 1° 5′ (centrigade) warmer than the surrounding air, he considers this difference of temperature considerable enough to be looked on as one cause of the mirage, as it had been observed on the banks of the Elbe, when the water was only 2° of Fahrenheit (0° 8′ cent.) higher than the air.

This explanation would perhaps be satisfactory, if the temperature of the surface was always greater than that of the air, when this species of mirage is present. But the contrary very often occurs, even in the observations recorded by Mr. Humboldt himself. In the instance already related of its appearance at Mingan, the temperature of the air was on the first day 57°, that of the water 48° 5′. On the following day the mirage was equally well marked at at 11, A. M. when the air was 60°, and the surface water 53° ; as it was at 9, A. M. when the air was only 53° and the water 51°. On these occasions the utmost care was taken to obtain the exact temperatures, free from any local cause of disturbance. That of the air was obtained by holding a thermometer at arm's length, with the bulb turned away, exposed to the wind, and without the shady side of the vessel. The temperature of the surface water was ascertained either from water drawn in a bucket, and examined instantly on its coming up, or by a register thermometer suspended over the side. When the former mode was used, the bucket was twice filled before the water was examined, in order that its temperature should not be influenced by that of the vessel. The following, from Humboldt's Note D, already referred to, are to the same purpose. He obtained the

angle with the zenith, by means of "a bird's quadrant divided into 96°, every degree of which is equal to 56′ 15″, the vernier subdivides the degree into 120 equal parts. The error of collimation 8′ 40″ (sexages. division) to be added to the zenith distances."

"1st Sept. 1800, at *23h. 10′.—The points of the islands and capes all appear elevated, suspended. Therm. in the open air in the shade 22° 6′; R. Deluc's hygrometer 45° 2′; the sea water 21° 4′; the sand of the plains between the town and sea 30° 8′ R.; depression of the horizon of the sea 95s 58′ 30″.

"The 4th Sept. at 5¼ h.—Cloudy, air very transparent, therm. 22° 5′, hygr. 41° 2′. The water of the sea at its surface 21° 8′. White sand on the shore 28° 5′. Depression of the horizon 95° 58′.—All the capes suspended, but the suspended part is only 5 or 6 minutes in length. Picuita is entirely in the air, its apparent length 0° 11′ 15″. At sunset the interval between the base of the island and the horizon of the sea diminishes as the horizon gets darker.—When the disk of the sun is hidden behind very dark clouds, the centre of Picuita rests on the horizon, the extremities of the island are then alone suspended.

"The 24th Sept.—Since the 18th, sky constantly clouded. The weather changes on the night of the 23d. Great transparency, the stars very brilliant, but not twinkling, even at the horizon. The 24th, great dryness, hygrometer at 21 h. morning, 32° Deluc, (67° Saussure,) therm. 21° 5′ Reaum. Depression of the horizon, the greatest I ever observed. Water of the sea 22°. The arid soil of the shore 32° 7′. Boracha is entirely in the air. The depression

* From noon.

of the horizon 96° 12′,† consequently 8′ greater than on the 4th September. Picuita often appears double, and inverted during the remainder of the day. At 22 h. therm. 23° 5′, hygr. 31° 5′. Depression of the horizon 96° 0′. At noon the depression of the horizon is still 96° 1′. Dead calm.

Here on the 1st of Sept. the air was 2° 7′ of Farenheit higher than the water; on the 4th, 1° 5′. On the 24th, at 9, A. M. it was 1,25 F. lower, but it rose at 10 h. to a 3° 9′ above it. The heat of the air at noon is not given, but it is probable that it increased very much during the calm, as the day advanced; while the surface water would not acquire by any means an equal increment. The mirage, highly marked, continued for the remainder of the day.

The object to which I would wish particularly to direct attention in these extracts, is the state of the hygrometer, and of the wind when it is given: as on these I am disposed to think the phenomena for the most part depend; for it is evident they could not be caused by the surface water being warmer than the air in these cases. The greatest difference of depression of the horizon was between that observed on the 4th and 24th. And the chief points of difference in the relative states of the atmosphere, was the greater dryness indicated by the hygrometer on the latter day; the clearness of the sky, and the calm.

A dry state of the atmosphere greatly facilitates the process of evaporation; and if there is a calm at the same time, the watery vapor will in some degree accumulate in the stratum of air next the surface; or, at least, the nearer any stratum of air is to the surface in this case, the greater will be the proportion of watery vapor contained in it.

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† 1-120 parts of a degree.

Hence, as the specific gravity of watery vapor is less than that of air, the lower strata will be less dense than the strata over them, as far as the immediate effect of the evaporation extends. If the rule, which regulates the refraction according to density, holds in this case, the lines of light passing from any object to a spectator, will be curved with the convexity downwards. That such a difference of density exists in the Egyptian mirage, I believe has been generally admitted: the lower strata of air being supposed to be expanded, and rendered less dense than those immediately above them, in consequence of the heat imparted by the burning sand. This explanation, however, cannot apply to the numerous instances of mirage seen over the surface of water, which is frequently only a few degrees warmer than the air; and is wholly inapplicable when the air is warmer than the surface, as in the cases already related.

The air may be in this form of mirage, sometimes above, at other times below, the temperature of the surface; but I believe its dew point will always be found lower. The extent of the shortening of the horizon, and the other phenomena connected with it, will be in proportion to the difference between the heat of the surface, and the dew point of the air in the first instance, as affording greater or less facilities to the formation of watery vapor; and in the next place, to the more or less agitated state of the air, by which the vapor is either allowed to remain near the surface, or is mingled with the general mass of the atmosphere.

The existence of the mirage in the sandy deserts, where no water is to be seen, may be urged as an objection to the mode in which I have endeavoured to account for its presence. But some of the places where it was observed in

the greatest perfection, both by Humboldt and Burkhardt, had been overflowed during the previous season; and though the surface was arid and heated, yet the deeper sands probably still retained much moisture. The heat communicated from the surface would gradually convert this into vapour, which would find a ready escape through the sand. In some parts of the desert brackish, or salt water may be found, merely by thrusting a stick into the sand; and in many, I believe, by digging to some depth. However, if the mirage of the desert, where the sand is often upwards of 20° hotter than the air, should be found to arise wholly from this cause, independent of evaporation, that does not affect the explanation of the mirage over water, the temperature of which is sometimes higher, and at others lower, than that of the air in contact with it.

I must now return to the mirage first described, the phenomena of which differ altogether from the last. Of these I shall recur to a few which strongly mark the difference between them. In the one we have been just considering, the horizon was always shortened or depressed; in the present, it seems invariably elevated. In the former, the picture of objects, which was frequently seen, was inverted, lay close to the object itself, and seen beneath it, or between it and the spectator; in the present one, I have never seen it inverted, and it is always seen above the real object, a considerable space occasionally intervening between them. In the one, objects are seen in their natural form; in the other, they are lengthened, or shortened, or horizontally distorted. In the one case, the reflected sky, which, from the shortening of the horizon, intervenes between the spectator and the object observed, reflects the latter, in the same manner as a mirror, or a perfectly still

sheet of water would do; in the other, there is no reflection of this kind, but the second object, when it is perceived, is seen, more or less perfect, above the real one.

The relative states of the surface and the atmosphere differ as remarkably as the phenomena just noticed. In the mirage with elevated horizon and distortion of objects, the temperature of the surface was always found lower than the dew point of the air, and the extent of the phenomena generally bore a relation to this difference, while it was short of that, which, by precipitating water in drops, occasioned the fine weather fog. Like the mirage with depressed horizon, it was much influenced by the wind, appearing in a calm, when the difference was only a few degrees, and not being seen when the difference was greater, if the wind was fresh. I have, however, seen both forms of mirage during very fresh breezes; in the one case, when the dew point was much below, in the other, much above the temperature of the surface water.

The extent to which the horizon is elevated in the mirage, I have as yet had no means of ascertaining by direct experiments, for want of suitable instruments. But an experiment made by Captain Bayfield, in July, 1829, at Anticosti, for the purpose of trying what trust could be placed on observations for time made with the natural horizon, bears strongly on the point, and shews that the apparent elevation really exists. By comparing the results of two sets of observations made, one immediately after the other, with the utmost care, on the forenoon of the 25th July, 1829, at Cape Henry, Anticosti, the result from those made with the natural horizon gave 32″ less time than those with the artificial. This difference of time, computed at the rate at which the sun then moved, was equal to

3′ 24″ of elevation; consequently, the natural horizon was then elevated to that extent. On this day, the temperature of the air, noted in our journal, was 56°, the dew point 51°; that of the surface water is not noted for the day, but I infer that it was 42°; as, on the 23d it had been 50° 5′, on the 24th, 46°, and on the 26th, 38°, the reduction being owing to a fresh breeze from the westward, which continued to blow, with little intermission, for the entire four days. At the time of the observations, the horizon was well defined, and there seemed no reason to expect any extraordinary refraction. The experiment was made for the purpose of trying what could be done under apparently favourable circumstances. In the subsequent part of the day, the mirage was observed, and excited suspicions as to the results, which were confirmed when the sights came to be calculated.

Our meteorological journal for 1829 and 1830 is deficient, generally, in the precise statement of all the facts respecting the air and the surface, which I am disposed to think occur in cases of mirage. In the first year, the mirage is not generally noticed; and in the second, we kept no record of the dew point, as we could not procure ether here sufficiently pure for the experiments. As far, however, as a judgment can be drawn from the imperfect data, viewed in all their bearings, the states of the air and surface correspond with those observed in 1831. Of these, the following only, of which particular notes were taken, are submitted; as, in them all, the subjects connected with the mirage were noted.

July 16, 1831.—At anchor between the Razades* and

* Rocks near the shore, and not far from the anchorage.

Bic, at 3½, P. M. a fog, which had covered the surface of the water for four hours, was melting away, The island of Basque* had its lower part enveloped in it, while the upper part was raised by refraction. The Razades had no fog or mist surrounding them, but were raised by mirage, in the usual way. A vessel, apparently on the border of the mist, seemed to have its masts and sails continued to an enormous height. Other smaller craft, nearer, were not at all distorted. On looking again, after a short time spent in examining the hygrometer, the fog had considerably diminished, the Razades and vessel resumed a natural appearance, the wall of fog round Basque was gone, but some mirage had taken its place, raising the shores to the semblance of a wall, but not affecting the higher parts of the island. Another vessel, to the northward, where the fog still continued, was partly hidden by it, and what was visible was much distorted, the distortion becoming less as the fog dispersed. Wind light; air, 54°; dew point, 47°; surface water, 43°; at 9, A. M. the air had been 48°; dew point, 46°; surface water, 40° 5′.

The fog returned between 6 and 7, P. M. and the islands on its verge, Basque and the S. W. Razade, were again thrown up; with an appearance on the latter, as if the spray of the sea reached as high as its top; the N. W. Razade, which was seen within the fog, had a natural appearance. The vessels in the offing, to the northward, on its edge, were partly distorted; one seemed to have two sets of jibs. The upper, which appeared on the level of the topgallant sail, seemed to be inverted; but, as a jib is triangular, it is not easy to ascertain whether it was so, or

* An island some miles farther to the westward.

not. Bic was for a long time thickly enveloped with fog, round its base, the top of the island shewing naturally above. Between 7 and 8, P. M. the fog dispersed in a great measure, from the lower part; and then it assumed the walled appearance which characterizes the mirage.

July 18.—The fog again today was followed by mirage, as on the 16th; one vessel, in the offing, seemed without masts; whilst others, somewhat farther off, seemed raised to an enormous height. On going up about two-thirds of the main rigging, the distorted appearance of the distant land ceased, whilst the shore near to still seemed thrown up, the same as on deck. The height, to which the latter seemed raised, was not great in either situation. On several other occasions, the distortion of the near shores was not perceptible from a moderate height in the rigging.[1]

Off Manitou River, Aug. 17, at 3h. 30m. P. M.—Air, 53°; dew point, 47°; surface water, 42°. The mirage on this occasion has been already described (p. 12). On the following day, there was no mirage. The air was very clear; temperature at 9, A. M. 59°; dew point, 36°; surface water, 41°; wind, N. W. fresh in the morning, but gradually subsiding.

The following are from the general meteorological journal:—

Bic, June 17.—Air, 54°; dew point, 48°; surface water, 43°; wind moderate. Mirage.

Mingan, Aug. 25.—Air, 57°; dew point, 52°; surface water, 48°. Wind, W. fresh. A slight appearance of mirage.

Aug. 26.—Air, 58°; dew point, 53°; surface water, 50°. Wind and mirage as yesterday.

Aug. 29.—Air, 53°; dew point, 42°; surface water,

49°. Wind, W. light. Mirage, with shortened horizon, differing altogether from the one previously observed during this year.

Aug. 30.—Air, 51°; dew point, 49°; surface water, 50°. Calm. Mirage, with the same phenomena as yesterday.

Aug. 31.—Air, 61°; dew point, 55°; surface water, 54°. Wind light. Mirage, with distortion.

Sept. 1, 4, P. M.—Air, 65°; dew point, 59°; surface water, 56°. Wind E. light. Mirage, with distortion.

Sept. 12, W. of Bic.—Air, 48°; dew point, 42°; surface water, 40°. Wind S. W. moderate—distant headland of Bic refracted with a walled appearance, which it retained at a height of two-thirds of the main rigging.

Passing up the river, we saw no more of the mirage with elevated horizon; that with the horizon depressed was observed when we reached Crane Island, on the 16th Sept. and almost every day for the remainder of the season, when we were in situations commanding a sufficient extent of prospect along the water.

It will probably be easy for persons familiar with optical demonstrations to account for the contrary curves taken by the rays of light in these two forms of mirage. In the one with elevated horizon, where the curves have their convexity upwards, the air on and near the surface, being cooled by the contact, is depositing watery vapour, and, from both causes, becoming proportionably more dense. The table appearance of the low land, and the seeming general level of all objects on or near the shores, as well as the level fog bank seen on the horizon, and the disappearance of mirage when we ascend to some height, all shew that the change in the state of the air, which causes it, is

confined to a certain, and tolerably equal, distance from the surface; and a sort of stratified appearance of the refracted shores would seem to indicate a succession of strata of different densities within this elevation. Or if a conjecture, hazarded in p. 11–12, is correct, and it seems to me the more probable cause, there is a succession of strata of air, in which minute particles of water are suspended, in different proportions. Can the occasional flower-pot appearance of rocks and small islands, in which the curves of the rays from the elevated parts are lateral or horizontal, be owing to the heated shore between the higher ground and the water, causing a state of the air over it, differing altogether from that of the air which rests on the cold water? This appearance, as well as I can remember, was only seen when some extent of low shore intervened between the more elevated land and the water.

In the mirage with depressed horizon, where the convexity of the curves is towards the earth, the air near the surface is acquiring watery vapour more or less rapidly, and becoming proportionably less dense. This effect will be increased when the temperature of the air being beneath that of the surface, the lower stratum of air not only receives an accession of watery vapour, but is at the same time warmed by the contact.

The rays of light which, in the latter, form the reflected sky, seem to be chiefly those that reach the surface at a great angle from the perpendicular, and are consequently most readily reflected, or refracted; for when an island, or headland near the horizon, consists of a low flat centre, with elevated extremities, as Crane and Goose Islands, the reflected sky or depressed horizon will be seen between the spectator and the low land, whilst it will not be observed

in the line of the higher points, though more distant, and consequently more favorable for its appearance. The remote line of the reflected sky in this case, corresponds with the varied elevation of the lower land, and not with its form at the level of the water. This seems also the reason why the extremities of islands, generally lower than their centres, and the points of headlands, appear raised. The inferior outline of the raised points, corresponding in a great degree with the superior, and the raised part is shorter or longer, as the point is more or less steep. The disappearance of the mirage, on the spectator reaching an elevation much above the level of the water in both cases, seems to prove that it is only the rays that pass near the surface, that suffer any considerable refraction. When, in consequence of the height of distant hills, the reflected sky was not observed in the direction in which they lay, I observed the hills to have that rich purple colour, so much admired in autumnal landscape, and this color seemed to depend on the state of the intervening air. Can it be that, in this case, the purple rays, being the most refrangible, are reflected by a medium that is not powerful enough to reflect the remainder of the rays constituting white light, in consequence of the angle of incidence not being sufficiently great.

If the forms of mirage, that have been here described, depend, as I suppose, on the difference between the dew point of the air and the temperature of the surface; or, in other words, on the formation or precipitation of watery vapour, it becomes an interesting subject of enquiry, whether the elevation and depression of the horizon, which characterizes them, bears any constant ratio to the relative states of the atmosphere and surface, when the phenomena of

mirage cannot be perceived. The observations I have had an opportunity of making, lead me strongly to think that such is actually the case; and the only measurement we have, that made by Captain Bayfield, at Cape Henry, Anticosti, tends to confirm the opinion.

As the accuracy of the result of many operations in nautical astronomy would be greatly increased, if the circumstances affecting the natural horizon, and consequently the apparent elevation or depression of celestial objects, could be clearly ascertained, the matter seems highly worthy of any attention that can be bestowed on it, and will probably form the subject of another paper on some future occasion, when, by means of suitable instruments, a sufficient number of facts and measurements can be obtained.

When the preceding part of this paper was laid before the Society, I had not had an opportunity of consulting any original papers on extraordinary refractions, except that of Humboldt, which is referred to; and I despaired finding any in Quebec. On examining the Library of the House of Assembly, however, which has been open since the close of the Session, I discovered that it contained a portion of the Philosophical Transactions, and the Memoirs of the French Institute. In the first, there are several papers on the subject—in the latter, I have as yet met but one by Mr. Biot.

As the causes of extraordinary refraction, assigned by some of the greatest philosophers in England and France, are directly at variance with those on which I have endeavoured to shew that it depends, it is necessary to refer to

those papers, in order to justify my dissent. At the same time I shall be enabled to connect the two forms of mirage, which I have observed, with those that are already known to the scientific world.

The first, in order of time, is Mr. Latham's. The extraordinary refraction enabled him to see the coast of France from Hastings, and to distinguish the colors on the heights, and the buildings. This was on a fine evening, after a very hot day. The weather, for some days previous, had been fine and clear.

Mr. Vince witnessed the phenomena of the mirage from Ramsgate, on the evening of the 1st August. From the water's edge, he could see the cliffs of Calais considerably above the horizon, although they are not often visible in clear weather from the hills. The ships in the offing presented, some double, some treble images. When there were two, the uppermost was inverted; when three, the second inverted; the upper erect. The real image was always the lowest, or next the observer. The refracted objects were all without the natural line of the horizon; those within it retaining their usual appearance. He observed several times a thick fog coming on the horizon from the opposite side, and rolling on it with prodigious velocity. There was no fog on the English coast—the unusual refraction was greatest to the eastward—the day had been extremely hot, the evening *sultry*, the sky clear, with a few flying clouds.

The mirages observed by Messrs. Latham and Vince agree in many respects: as the localities, which differed little; the time of the day; the warmth of the weather for some time previous; and the clearness of the sky. The only difference seems to be in the intensity of the phenome-

na. Both instances I can, without any hesitation, refer to the first form of mirage, which I have endeavoured to describe; that with an elevated horizon and distortion of objects seen. For the phenomena of this mirage is so familiar to us; it is so much an every day occurrence at certain seasons, that we can instantly and easily recognise it in any of its forms.

The mirage, described by Mr. Huddart, differed in no cirumstance from the mirage with shortened or depressed horizon, so common on the upper part of the St. Lawrence in the months of September and October. Mr. Huddart considered the extraordinary refraction to be the effect of evaporation, and explains the manner in which it affects the air, very much in the same way I have supposed it to do. The second image seen inverted *between the real object and the observer*, he attributes to refraction.

Mr. Vince attributed the mirage, which he saw, to the fog. As the strength or direction of the wind is not mentioned in either of the papers, it is probable the phenomena occurred during calms.

In 1799 Doctor Woolaston published his beautiful experiments, by which it was shewn that all the phenomena of mirages could be explained by the curves given to rays of light in passing through a transparent medium, consisting of a succession of strata, of different densities. From his experiments on evaporation, he came to a conclusion, that its effect would be to increase the refractive power of the air, with which the watery vapour is mixed. Hence he attributes the phenomena seen by Mr. Vince to evaporation, and those seen by Mr. Huddart solely to the temperature of the water being greater than that of the air above it, by which means the strata nearest the surface were expanded

by the heat communicated by the water, and thus rendered less dense than the strata lying over them. Evaporation, he considers, would have a contrary effect, by increasing the refractive power of the air. The little difference of temperature with the water, in many cases, and consequently slight effect in diminishing the density of the air in contact, he considered would be compensated by the extent and equality of the surface, along which the rays pass.

Notwithstanding our deservedly high estimation of Dr. Woolaston, as an experimental philosopher, and the deference which is justly due to his authority, I must venture to enquire into the circumstances of the experiments, on which his opinions of the effect of evaporation on the refractive powers of the air are founded, as they seem to have been received implicitly ever since.

A board 5 feet long was wetted with ether, alcohol and hot water from a sponge successively. With the first, the refractive power of the air over the board was so much increased, that objects seen through it were elevated nearly half a degree; with alcohol, 15′; with water, scarcely perceptible. But on running a sponge, wet with hot water, over a board 10 feet long, the refraction was equal to an elevation of 3′. When the vapour was confined by boards on each side, the refraction with the two first substances was greatly diminished; and when water was used, it became imperceptible. But on removing the side boards, so as to allow the wind to pass briskly over the wetted one, the full effect was again produced. Hence he infers that a light breeze is more favorable to the appearance of the mirage, that depends on evaporation, than a calm.

Passing over the experiments with ether and alcohol, both as foreign to our subjects; and as the density and

refractive power of the vapour arising from them is ascertained to be so much greater than that of air, let us examine that with the hot water. Here the first thing that meets us is, that the simple mixture of the watery vapour with the air, has no sensible effect, if it is confined over the surface that produced it. But in the instances of mirage already detailed, where the state of the air and water was most favorable to evaporation, the vapor formed must have been retained near the surface from which it sprung, by the very extent of that surface, and the absence of wind, for the mirage was always greatest in a calm, and was lessened by the lightest breeze. The hygrometic state of the air, or its temperature, are not noted in Dr. Woolaston's experiments: it may have been already nearly charged with moisture. Besides, when the surface water is very much warm than the air, *if there is a fresh breeze*, we have seen (p. 9) that a fog results apparently from vapor being formed in greater quantity, than the air can receive it under the circumstances; and frost smoke, which depends on the same cause, is a common occurrence. It is not improbable, from the heat of the water employed, that a state of the air approaching this kind of fog took place. Such a state would be exactly similar to that which seems to hold in the cases approaching to fog, where the water is colder than the dew point of the air, and where we know that the refraction of the air is greatly increased.

That the mirage described by Mr. Vince could not be owing to evaporation, I can have no hesitation in asserting, from having seen similar phenomena constantly attended with a state of the air and surface, from which deposition alone could result. And the fog observed by Mr. Vince is an almost convincing proof that such a state existed at the

time. The evening too is described as sultry, and it had been preceded by warm fine weather for some days. We frequently found that in such weather, the air becomes gradually changed with moisture.

The phenomena, in both Mr. Latham's and Mr. Vince's report, occurred in the narrow strait between France and England, where, from a strong tide meeting obstruction from the shape of the land, the cold deep water, from its greater density, is likely to come to the surface.

Observing that the rays of light passing through air in contact with a heated body, were deflected in the same manner as in the mirage described by Mr. Huddard, Dr. Woolaston attributes the latter, as already mentioned, solely to the effects resulting from the temperature of the surface water being higher than that of the air, which rests on it. That this cannot be the cause, is evident, as we have seen that a similar mirage occasionally occurs when the temperature of the air is equal to, or even much higher than that of the surface water.

The article on extraordinary refractions by Mr. Biot, in the Mem. de L'Institute, commences with a review of the descriptions and opinions previously published on the subject. He disapproves of Mr. Huddart's mode of accounting for the mirage he observed; as, from many reasons, he concludes that the admixture of watery vapour with the air, would rather increase than diminish its refractive power. (Tome x. p. 2.) In the same manner as Dr. Woolaston, he attributes the phenomena, in this instance, solely to the effects arising from the surface water being warmer than the air above it; and approves of his inference, that double images are owing to a variation of density contrary to that which ordinarily exists. (p. 7.) In the instance of

mirage described by Mr. Vince, he thinks the water was warmer than the air, and supports his opinion by referring to the temperatures recorded in London on the same day. These were at 7, A. M. 64° F.; at 2, P. M. 82° ; greatest heat 83°. As the following day was not near so warm, he supposes that the temperature of the air in the evening must have been descending fast, so as to become lower than that of the water, which is not liable to so quick a change. He does not seem to have comprehended the force of the word *sultry* used by Mr. Vince in describing the state of the air at the time. Thinks what Mr. Vince describes as fog was only the tops of the waves highly refracted.

In taking night observations on the coast of Valencia, Mr. Biot once saw a light on a mountain, in the island of Ivica, multiplied to three, four or more, all in a vertical direction, (at other times and places the light was only lengthened vertically.) In the morning, on looking in the same direction, the sea was seen covered with masses of mist. These mists did not exist the previous evening, but had been formed during the night. He afterwards constantly observed this circumstance, wherever the same phenomena of extraordinary refraction recurred. He does not think that the mist contributed to produce the extraordinary refractions, but that as it indicated a perfect calm, it ought frequently to accompany their appearance. (p. 15 and 16.) In his measurement of the dip of horizon, he found the depression much increased at the rising of the sun ; and he remarks that the mirage with depressed horizon was greatest, ceteris paribus, when the barometer was highest. On the other hand, I find in the tabular account of his observations, that the horizon was most elevated on the 10th Feb-

ruary, when the observations were made with rain at hand, or in the interval of showers (p. 172 and 173). There is no record of the state of the hygrometer, but we know that a dry atmosphere generally, though not always, accompanies a high barometer; whilst the frequent showers are a tolerably certain indication of an air charged with moisture. Mr. Biot, however, considers that a knowledge of the relative temperature of the air and sea is all that is necessary for correcting the errors of the dip of the horizon.

The last of these papers, in which I find the effect of watery vapour on the refractive power of air considered, is that of Mr. Ivory in the Philosophical Transactions for 1823. He considers that the neglect of the effect of aqueous vapour can have little influence on the calculations for reducing apparent altitudes, as other disturbing causes have so much greater influence on the results. "Hawksbee (he says) first determined that air refracts light in proportion to its density; there is even good reason to think that this conclusion of Hawksbee is not materially affected by the various quantities of aqueous vapour contained in the atmosphere at different times." Again, on the uncertainty of the amount of refraction, he observes that "In the English surveys $\frac{1}{10}$ is allowed for terrestrial refraction—the French mathematicians allow $\frac{1}{12}$—it varies from $\frac{1}{2}$ to $\frac{1}{24}$. No reliance can be placed on the mean even of many observations, as it differs so much in different places. If we examine a set of observed refractions, it will be easy to discover instances in which the true refraction has diminished, when, according to the instruments employed, it ought to have increased; and the contrary. The real cause of such anomaly is undoubtedly the irregular changes that take place in the remote parts of the atmosphere,

which are not indicated by the barometer and thermometer."

If, in addition to the indications of the barometer and thermometer, the dew point of the air had been also noted, is it not probable that some light would be thrown on the cause of these discrepancies? I can only suppose that the influence of watery vapour in terrestrial refraction has been under-rated or overlooked, from the different effects it produces, when newly formed, and in the state of a perfect gas; and when returning from any cause to the liquid state.

I shall conclude this paper by extracting part of a table of the observations on the dip of the horizon, made by Captain Parry and Lieutenant Foster.* The original table contains observations in 1823 and 1824; but those for 1823 were useless to me, as there was no hygrometric register kept on that year. The dew point is not noted in the original table, as it is probable that there was no suspicion of any connexion existing between its temperature, compared with that of the surface, and the dip. In endeavouring to supply this omission, by giving the dew point for the days of observation, taken from the general meteorological journal, an approximation is the most that can be obtained. But as the changes of the dew point during the day are often very trifling, though the temperature may vary much, the dew point observed within an hour or two of the time of observation, cannot differ materially from what it would be, if observed at the exact time. The general result is in accordance with the views entertained in this paper, although some of the observations might lead to a contrary opinion, if the circumstances under which they were taken

* Parry's third voyage.

were not inquired into. On the 6th of June the temperature of the surface was below the dew point, and the horizon was elevated. On the 10th the same state existed in a greater degree, but the results of the observations varied, for in one of three sets of observations it was found depressed. The variable state of the horizon on this day is noted in the general remarks.

On the 9th of July, all the observations but one shewed an elevation of the horizon; but the temperature of the surface water, which was below the dew point in the morning, was above it in the afternoon. The situation of the ship, however, at this time, makes it very improbable that the temperature of the surface water towards the horizon, was near as high as it was found to be close to the vessel. In the morning there were several ice-bergs in sight, and the "pack" within eight or nine miles. In the afternoon the horizon was hazy, and ice-bergs near. Referring to the journal for this period, we find Captain Parry saying "Light northerly winds, together with the dull sailing of our now deeply laden ships, prevented our making much progress for several days, and kept us in the neighbourhood of several ice-bergs. We counted from the deck, at one time, no less than 103 of these immense bodies, some of them from 100 to 200 feet in height above the sea!" Under these circumstances, it is extremely unlikely that the surface water would be so high as 38° for any considerable extent; and the opinion is strengthened by finding that it was as low as 29° on the following morning. The different results of the two first sets of observations on this day, seem to accord with what I observed respecting the mirage that occurs in similar states of the air and dew point: namely, that the extraordinary refraction is often lost by

an increased elevation of the observer. The observations on the 10th and 11th shewed an elevation of the horizon, on one occasion, to the extent of 1′ 3″; the dew point was higher than the temperature of the surface water on both these days.

The extent to which the horizon was found raised, in these observations, is very small, in comparison with its elevation when observed at Anticosti by Captain Bayfield. The difference probably depends on the lower position of the observer in the latter case, (as he stood near the water's edge) and the greater difference between the temperature of the surface and the dew points, being about 9° at Anticosti, whilst in Captain Parry's observations it did not exceed 3°.

Observations on the Dip of the Horizon at sea, by means of Doctor Woollaston's Dip Sector, made by Captain Parry, R. N. and Lieutenant Forster, on board the Hecla, in the voyage for the discovery of a N. W. passage, in 1824.

Date, 1824	Time.	Observer.	No. of Observations.	Height of the eye in feet.	Dip. Tabular.	Dip. Observed.	Difference tabular being.	Temp. Air.	Temp. Sea.	Dew Point. 9 A. M.	Dew Point. 3 P. M.	Dew Point. 9 P. M.	Barometer.	Points of the horizon observed.	Wind. Direction.	Wind. Force.	Weather and Remarks.
	h. m.			ft in	′ ″	′ ″	′ ″	°	°	°	°	°					
June 6	10 00 A.M	P.	8	13 6	3 37	2 45,6	+0 51,4	52,5	49,5	51	52,5	52	30,24	N. by W.—S. by E.	S. S. E.	Moderate.	Cloudy.
10	1 30 P. M.	P.	10	15 0	3 49	3 17,5	+0 31,5	52	48	52	52	52	30,16	N. E.—S. W.	E.	... ...	Sea smooth; horizon variable; weather moist; horizon clear at the last observation.
...	... ...	F.	6	15 0	3 49	4 09,1	—0 20,1	52	48	...	...	...	.....	... ...	... ...	... ...	
...	... ...	F.	6	15 0	3 49	3 42,5	+0 6,5	52	48	...	...	...	.....	... ...	... ...	... ...	
July 9	8 00 A.M.	P.	20	19 0	4 19	3 42,2	+0 36,8	36	34	36	35	33	29,88	S. E. by S.—N. W. by N.	N. W. by N.	... ...	Very fine; several ice-bergs in sight; the "pack" 8 or 9 miles west.*
...	... ...	F.	6	22 0	4 37	4 37,5	—0 0,5	36	34	...	...	...	.....	S. E.—N. W.	.. ..	... ...	
...	Noon.	F.	10	22 0	4 37	3 50	+0 47	39,5	36	...	...	...	29,82	N. W. by N.—S. W. by S.	... ...	... ...	
...	0 30 P.M.	P.	20	18 6	4 14	3 29,4	+0 44,6	39,5	36	...	...	...	.....	... ...	....	... ...	
...	4 00	F.	10	23 0	4 43	3 57,9	+0 45,1	38	38	...	...	...	29,78	E.—W.	N. by W.	Fresh.	Sky clear above; hazy near the horizon; some ice-bergs near.
...	4 15	P.	10	19 6	4 20,5	3 19,7	+1 00,8	39	35,5	...	...	...	.....	N.—S.	... ...	... ...	
10	11 40 A.M.	P.	12	19 0	4 19	3 48,4	+0 30,6	34	29	32	32	30	29,83	... ...	N. W.	Moderate.	Clear in zenith; clouded in horizon; ice in south horizon.
...	Noon.	F.	10	19 0	4 19	3 47	+0 32	34	29	...	...	...	.....	... ...	... ...	... ...	
11	7 40 A.M.	P.	20	18 6	4 14	3 10,2	+1 03,8	33	30	33	33	30	29,70	S. E. by E.—N. W. by W.	N. W. by N.	... ...	Clear and cloudless; ice seen in N. W. by W.
...	9 00	F.	6	22 0	4 37	3 49,1	+0 47,9	33	30	...	...	...	.....	N. N. E—S. S. W.	... ...	... ...	
...	... ...	F.	6	22 0	4 37	4 05,8	+0 31,2	33	30	...	...	...	.....	N. N. W.—S. S. E.	... ...	... ...	

* There is a mistake in the original, both in the tabular dip of the first set, and the sign of difference. On the 8th, the dew point was 39° at 3, P. M. and 38° at 9, P. M. As it seems to have been falling gradually, it was probably a trifle higher than 36° at 8, A. M. of the 9th.

Specific Gravity and Temperature of the surface, and deep water, in various parts of the St. Lawrence, and at different seasons. The Specific Gravity corrected for the error of the instrument, and reduced to 50° Fahrenheit.

Place and Date.	Temp. of the Air, at 9, P. M.	Temperature of the water when taken up.	Depth from whence taken.	Time of Tide.	Specific gravity at 50°.	General Remarks.
	°	°				
Isle Plat, Oct 15, 1831	44	52	Surface.	No tide.	1,0003	
Quebec, Sept 12, 1830	52	61	... ...	3 h. ebb.	1,0006	
Grosse Isle, May 29, 1831...	62	57	... ...	4 h. ebb.	1,00044	
Crane Island, Dec 30, 1831.	58	57	... ...	2 h. ebb.	1,00034	
Do do do	...	.....	... ...	H. W.	1,0006	
Do do Sept 16.....	50	62	... ...	L. W.	1,0010	
Opposite the Pillars, June 6	62	60	... ...	L. W.	1,0007	
Do do do	70	62	... ...	H. W.	1,0017	Was slightly brackish.
N. Channel, off Malbaie, 9th	55	54	... ...	L. W.	1,0117	
Brandy Pots, Jan 29, 1830...	50	48	... ...	3 h. ebb.	1,0170	Sp.gr. the same at 5 hours flood, temp. 47°.
" July 9, "...	57	47,5	... ...	3½ h. ebb.	1,0178	
E. of Razades, June 26, 1831	49	42	... ...	3 h. flood.	1,0203	
Bergeron, July 5, "	62	40	... ...	1½ h. ebb.	1,0230	
E. of Red Island, July 5, "	...	42	... ...	3½ h. ebb.	1,0207	
West of Bic, June 26, "	49	46	... ...	L. W.	1,0182	
East of do, July 12, 1830...	59	46	... ...	4 h. ebb.	1,0204	Same in the flood.
Matane, 18, " ...	69	62	... ...	... ...	1,0189	
10 m. N.N.E of do. 8th, 1831	64	60	... ...	3 h. flood.	1,0180	Calm.
Do do do	65	54	... ...	5 h. flood.	1,0187	Wind W. freshening.
Do do do	...	35	30 fath.	... ...	1,0260	During the calm.
Do do do	64	34	50 fath.	... ...	1,0265	" "
Off Point des Monts, July 9	62	57	Surface.	5½ h. flood	1,0172	Calm, after much rain and fog.
" "	...	35	100 fath.	... ...	1,0275	
Trinity Bay, 10	52	37,5	Surface.	H. W.	1,0260	A gale from the W. the preceding night.
Bay of Seven Islands, Aug 3	61	53,5	... ...	4 h. ebb.	1,0202	
Ellis B. Anticosti, July 28, 1830	61	59	... ...	5 h. ebb.	1,0236	
Heath Pt. do Aug. 11, do	61	58	... ...	3 h. ebb.	1,0243	