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III. ON THE METEOROLOGY OF THE PART OF THE ANT- ARCTIC REGIONS WHERE THE "DISCOVERY" WINTERED.

By Lieut. C. W. ROYDS, R.N.

THE physical geography of a region is affected in various ways by the meteorological conditions. I had charge of the meteorology during the three years that the *Discovery* was absent from England, including the two years and two months that she was within the Antarctic circle. I have, therefore, been told off to submit a paper on the meteorology of that part of the Antarctic Regions where we wintered, with special reference to its physical geography. I have endeavoured to fulfill this task to the best of my ability, but I am impressed with my incompetence to undertake it.

I need not describe in any detail, the route of the ship during the navigable season of 1901 to 1902, as that has already been done by more competent hands. I need only remind my audience that we passed down the eastern coast of Victoria Land, from Cape Adare to Cape Crozier, examined closely the face of the great ice-barrier throughout its entire length, and discovered high land to the eastward.

Throughout the passage down the coast we experienced more or less light south-easterly winds, except for a very heavy gale from the south-west off Coulman island, which lasted for three days. The winds we experienced whilst passing along the barrier were from the south-east to south-west with few exceptions, and very cold winds they were, as they had passed over the many hundreds of miles of barrier to the southward before reaching us.

It is necessary that I should describe more fully the position of our winter quarters, especially with reference to the amount of shelter caused by surrounding land. The ship was in a small bay of about a quarter of a mile in depth. All round, from north-north-west through east to south-east, there was land rising quickly to some height. In the north-north-west the hills were 400 feet high, and these extended to north-east, and then a hill of 1000 feet in the east, and one of 700 feet in the south-east. Between the east and south-east was a deep gully, or gap as we call it, which opened out on to the ice-barrier. From south-east through south and west to north-west we were entirely open except for land 20 to 50 miles away. From north-west back to south-west was the Albert range, rising to peaks of 15,000 feet, and to the south were some islands 3000 feet and land rising to 8000 feet.

In our bay there was a very pronounced local wind, namely from an easterly direction, and it was no uncommon thing for one to leave the ship, blowing a fresh gale, and, having walked a mile to the south and rounded Cape Armitage, find it a dead calm. Very many instances of this might be quoted, only time will not permit.

Before proceeding further, I should like to say that any temperatures or barometric readings that are mentioned are entirely uncorrected, and in the case of the means they are not issued as correct from the Meteorological Office, and are only the results as worked out during the time we were in the south. In every case the temperatures are Fahrenheit, and the winds are true.

In speaking first of the temperatures, there is very little to say, on account of the observations not being worked out. The coldest temperature registered at the screen was $-59^{\circ}\cdot 5$ on August 20 of our second year, our first year's minimum being $-50^{\circ}\cdot 5$ in the same month of August. The corresponding maxima for the two years were $+39^{\circ}$ in 1902 and $+42^{\circ}$ in 1903, curiously enough on the same day each year—December 26.

It was unfortunate that, on account of the ship being left with so few hands from November, 1903, to February, 1904, night observations had to be discontinued, and so I am unable to compare the monthly means of the two years. This will be done; as, although we have not the eye-observations for those few months, we have the records of the self-recording instruments the whole of our stay in those regions. At one time I thought of trying to compare our temperatures with observations of other expeditions, but on looking into it, I decided that they were not comparable, except in the case of the Cape Adare observations. All the remainder were movable stations, and were taken at sea, whilst ours and the Cape Adare ones were fixed land stations.

In comparing the first year's means with those of Cape Adare, one finds that the difference is roughly about 7° lower at our station. Two things can account for this—latitude and locality, as the close proximity of that huge mass of ice of the barrier to our station must necessarily reduce the temperatures. There is one marked similarity between the two stations, and that is the extraordinary rise of the mean for July. I account for it by the very long duration of southerly gales we experienced, during which the temperatures invariably rose to above zero. At Cape Adare, also, July was their stormiest month. In our second year, on the contrary, July was our coldest mean, and we had a comparatively calm month, the percentage of calms being the highest for the whole time we were south, namely, 34.1 per cent. In comparing the temperatures for the two years, you will notice that the second is considerably colder, and one can reason it out to some extent by the fact that there was more ice in the vicinity, and that ice was thicker than in the first year.

Whilst on the subject of temperatures, I might speak about a minimum thermometer we placed on a stand $1\frac{1}{2}$ miles from the ship to the south, and well clear of all land. The difference between the readings of this thermometer and the one in the screen was extraordinary, especially in calm weather, 10° , 15° , and even 20° being a common difference. For instance, on August 10, 1902, the temperature at the screen was -35° , with light easterly airs, that at Cape Armitage being -50° . Again, on the day that we recorded our lowest temperature of $-59^{\circ}\cdot 5$ at the screen, the corresponding minimum at Cape Armitage was $-64^{\circ}\cdot 6$; the lowest reading at Cape Armitage was $-67^{\circ}\cdot 7$, or nearly -100° of frost on May 16, 1903. Whether the fact of our screen being more or less surrounded by high land made that difference alone, I wouldn't like to say.

In referring to the spring journeys, I can only say that if any one seriously wants to know what real discomfort is, coupled with extreme cold, let that person go on a sledge journey, leaving the ship early in September, and I think he will agree with me that it is the acme of discomfort, and will not remain out a day longer than he can help. With regard to the barometer, I have very little to say, with the exception that, as in former expeditions, we found the pressure to be low. As a means of warning for the gales, it was not of much value, but very often showed the approach of a cold snap by falling generally. There is rather a peculiar thing that has happened to all the barometers. On comparing them with the standard at Kew, it is found that they have all increased their corrections. Whether the temperature has affected the glass or cistern to a permanent degree is not certain, but the fact remains as stated, that the corrections are all larger.

The direction of the winds is my next subject for discussion. Our prevailing wind was from an east to south-east direction. There is very little doubt but that the winds are the worst part of those regions. The question to be answered is whether the common condition down there is windy with intervening calms, or whether, on the other hand, the calm conditions prevail, broken by strong

winds. This can only be solved by the working out of the numerous observations, summarizing the whole of the work done down there; and personally I should be inclined to say that the windy condition prevails, and life made possible by the calms. Without having compared the two years' observations, I should say that our first year was infinitely more boisterous than the second; but whether or not this will be the case when the work is completed, I shouldn't like to say. I spoke earlier about the local winds, and I cannot help mentioning them again, as they were so marked, and noticed by every one on board.

Throughout the whole of our stay in winter quarters, we recorded no wind from the west or north-west, except occasional light airs. Winds from the north were more common in the summer, and especially during our last one. Gales from the south-east were generally accompanied by low temperatures, and on more than one occasion the temperatures have been below -40° , with a wind force of 7 to 8 blowing, making life outside the ship far from nice. But the worst gales were from the south and south-west, and we used to call them blizzards, as they were invariably accompanied by absolutely blinding drift snow. It is really a very difficult thing to any one who has not experienced a gale of this description to know what happens.

The air is entirely filled with driving snow, which strikes you just like a sand-blast. You cannot face it, but have to stumble on to wherever you may be going with your head down and arms protecting your face; and even could you face it, you are not able to see a yard all round you. I will give you an instance of how blinding they are. Whilst preparing for the winter after our arrival in the bay, and after the sea had frozen over, posts connected with ropes were led to every place where it was necessary to go every day—that is, to the magnetic huts and living hut, and to the meteorological screen.

It was during the latter part of the first winter that what might have been a serious affair happened. You may have heard that we had at times concerts, theatricals, and at one time a nigger troupe, to liven things up. Now, it was no good rehearsing these things in the ship, as every one would know exactly what was going to be done, and the jokes to be made, consequently it meant the performers going over to the living hut for the rehearsals, and as in this palace of varieties there was invariably a temperature of -20° and below during the time we were rehearsing, it was no great pleasure playing the piano. It was on one of these occasions that I had taken the party across to the hut to rehearse the nigger troupe, and it was blowing a hard blizzard, with exceedingly low temperatures. On arrival at the hut, we found two officers, Mr. Skelton and Mr. Bernacchi, taking pendulum observations, but they left before we started our rehearsal. We finished in about an hour and a half, and then started back to the ship. As usual, one cautioned the men to keep together, and not let go the rope which led back to the ship. We had got about halfway across, the whole distance being only about 200 yards, when I heard a shout, and knew that, as it was none of my party, some one must be adrift from the ship. We opened out, and found Mr. Skelton and Mr. Bernacchi, who were quite lost, and who had been wandering about for an hour and a half, unable to find out their whereabouts. Both were more or less frost-bitten about the face, and were exceedingly glad to have been found.

One could quote many instances of the like nature, all pointing out how absolutely helpless one is in a blizzard, unless you know exactly where you are. During these blizzards the ship gets more or less buried, and everything else besides. After one or two of these, it is always necessary to lift and move the meteorological screen, as it is invariably buried. You can imagine how impossible it is to measure the snowfall under these conditions. In fact, to tell the truth, it

is always a matter of some surprise when, after the blizzard was over, one was even able to find the snow-gauge, which was completely buried under as much as 3 and 4 feet of snow.

The great peculiarity of these blizzards was the invariable rise of temperature. They always came from the south and south-west, and once the wind got back to the south-east or east the temperature always fell again. Great fluctuations in the thermograph curve always gave us some warning of an approaching blizzard. A glance at the map will show you that these south-west gales came over high land, which would cause more probably this effect, rather than the idea that they come over open water. I am unable, I am sorry to say, to speak intelligently on this subject, and will leave it to others for solution; but this I would like to say, that I have always understood that the Föhn wind is a dry wind. I may be wrong in my supposition, but our south-west winds always brought drift snow with them, and I should say that they also brought snow along with them. Our heaviest gale was on July 19, 1902, between the hours of 4 p.m. and 8 p.m. of the next day. From 10 p.m. to 10 a.m. the Robinson's anemometer gave an hourly velocity of 85 miles. By the latter part of the gale the temperature had risen to $+15^{\circ}$, although it had been below -20° the day before, and dropped again immediately the wind went to the east. We never got a minus maximum temperature for the month, purely by reason of these blizzards bringing the high temperatures.

To get caught in one of these gales on a sledge journey was no joke, and, speaking personally, my party was five days in a tent unable to do a thing. At another time in the same spot, Dr. Wilson was for nine days weather-bound, and, in fact, it was an uncommon thing for a party away sledging not to be laid up for one or more days. The winds experienced by the parties away sledging are very interesting. Throughout the captain's southern journey, he experienced southerly and south-westerly winds. When on the inland ice-plateau, 9000 feet above the sea-level, he recorded continuous west-south-west winds, whilst at the same time, whilst on my journey to the south-east on the barrier, we got perpetual south-west winds, and all the sastrugi—those are the snow-ridges caused by the wind—pointed to south-west, and to all appearances it is the prevailing wind. At the ship during this time they recorded continuous strong winds, but more or less from an easterly direction. Our second year's sledging season was considerably worse for sledging conditions than our first, and all the parties, on their return, complained of incessant winds, which delay a sledge-party dreadfully. It was at Cape Crozier that a party always got strong gales. Across the bay between Cape Armitage and Terror point, a strong wind was never felt; neither is there any indication of anything stronger than light airs.

I have been talking all the time about the surface currents, except in the case of the western journey, and now I will just say a word or two about the upper currents. We were very fortunate in having such a splendid indicator of the upper currents so close to us as we had in the smoke of Mount Erebus, the only pity being that it was not visible from the ship, but one had to walk out about 300 yards or so before we got it in view. Whenever any one went for a walk or was in sight of the mountain, they always, on their return, reported which way the smoke was going. The usual direction was to the north-east, pointing to an upper south-westerly current, and similar to the winds experienced by Captain Scott on the inland ice. We invariably expected wind if we saw the smoke going to the north-west, and were seldom disappointed. It was a most common thing to see the smoke going north-east at the same time you, on the level, were in a strong easterly wind, and I have noticed detached clouds, only about 2000 feet below the summit, passing quickly to the west, while the smoke was going in a steady stream to the north-east.

With regard to the precipitation, as I have remarked before, it was impossible to determine it during the blizzards. Throughout the winter months very little snow falls; but during the summer months we had very heavy falls of snow, sometimes small dry flakes, and at other times the more common English snow-flakes, damp and wet. At times there was considerable precipitation during clear weather of most beautiful ice-crystals, and whilst sledging the effects of the sun on these crystals was most dazzling. Throughout our stay inside the Antarctic circle we recorded no rain; only on one or two occasions did we get any large accumulation of fog-crystals so common on Ben Nevis. I might mention that fogs are not nearly so prevalent as is supposed, unless we were lucky in not meeting them. The amount of sunshine down there is a great deal more than we had been led to expect, and in the summer we used to get day after day of most glorious sunshine day and night.

Of other phenomena the mirage is the most common, and at times is very considerable. Haloes and coronæ are also very common, and we have seen some very beautiful and complicated effects from the former.

I trust that these few notes on our meteorology, necessarily made under disadvantages owing to our results not having yet been worked out, will be of some use. I think they may give a sufficiently clear general idea of the conditions for considering the relations between the meteorological phenomena and the physical geography of the region.

After the paper, Mr. SHAW said: The information that the meteorologists of the expedition have brought back is exceedingly interesting from many points of view. One point interests me particularly, because it confirms an idea which I had in my mind in the early summer before the expedition came back; it is the difference of the direction of the smoke of Mount Erebus from the direction of the wind at the surface. I had come to the conclusion that it was probable that the arrangement of affairs towards the south pole was a cold layer of air at the surface—about that one was sufficiently certain—and above that a layer of upper air moving independently of the lower air; and that, whereas the surface layer would probably circulate, taking the average for the year, from east to west, so that the surface wind would probably be an easterly wind, the upper air would, on the other hand, circulate in the opposite direction round the pole, so that the winds to be expected in the upper regions would be westerly winds.* One of the great good fortunes of this expedition, from a meteorological point of view, is that their winter quarters were close to Mount Erebus, and that they could see the smoke by going not further than 300 yards. It does appear that the general drift of the smoke was towards the east, whereas the wind on the surface was, generally speaking, from the east, showing a circulation in the opposite direction. That is a matter of very considerable importance to the general theory of meteorological currents. There is another point with reference to the surface winds which raises a question of interest, though I am afraid we shall be unable to solve it. It concerns the actual observed directions of the surface winds from day to day. If you consider the condition of affairs in the southern regions you will notice that they are entirely different from the condition of affairs that we have in temperate regions. I am speaking of the winter time, the most interesting time there. Here the dominant agent which causes local disturbances in the general meteorological distribution is, of course, the sun, and it is extremely powerful. There, the sun being absent, the dominant agent is the radiation to the clear sky. In our region, if the sun shines

* See *Proc. Roy. Soc.*, vol. 74, p. 28. 1904.