of weather. As our study advances, some attempt is made to label air masses, and to show warm and cold fronts. The occluded front is carefully avoided, because the two teachers, Mr. Gayle Chubb and myself, don’t know much about it. Then, too, we must avoid introducing too much detail, especially technical detail. It is very easy to “overshoot,” not only in high school but also in college. Probably the most difficult problem in all teaching is to strike a “happy medium” whereby the teacher feels that a majority of the students in a class are at least grasping the fundamentals of a course.

Needless to say, we emphasize the important part that meteorology plays in the field of aviation. Aviation is relatively new, and appeals to young people. This is a good device to catch the interest of our students. We used (before our cut in teachers’ salaries, which is now 22%) to take our classes on a field trip to the Kansas City municipal airport. The field trip, however, has lost its appeal, to many teachers because of the dangers involved in automobile transportation.

Both of our local newspapers print the daily weather map along with much weather data. We often require students to clip the maps from the papers and to paste them in their notebooks. Otherwise many would never look at them. In reporting the weather, our newspapers still feel compelled to publish the name of one meteorologist as being responsible for the entire weather story. This makes it possible for everybody to blame all their misfortunes on the weather man. Time after time we hear people say; “If you want to know what the weather will be, just expect the opposite of what forecaster Jones said in the paper.” Journalists cling to the “human touch” idea in writing stories, and a man’s name in the weather story gives the news a thrill that makes the hair stand on end. Why the papers can’t speak of the “official Weather Bureau forecast” and let it go at that is hard to understand.

In conclusion, it should be noted that many of our high school students remark at the end of the school year that they enjoyed the study of weather and climate more than any other part of earth science. To others, however, the geological side of the course, involving the study of natural resources, seems more interesting and valuable.

The Use of Solar Energy for the Melting of Ice
H. LANDSBERG
The Pennsylvania State College

In a general review on the relationship between glaciology and geophysics Prof. H. F. Reid (1)* states: “It is evident that the more important variations of glaciers are to be explained by variations of climate. . . There is a reflex action that is important; a large glaciated area reduces the general temperature of the region and thus tends to increase the accumulation (of glaciers) and the extent of the area. If, for any the extent of the glaciation will become smaller, the general temperature of the region will rise, and the retreat will be hastened.”

The self-perpetuation of an area covered by ice or snow is largely determined by the radiation properties of the surface. The melting of the ice or snow depends to a considerable extent upon the amount of energy absorbed from solar- and sky-radiation. It is well known that a large
amount of incident radiation is rea-
son, the accumulation diminishes,
ected by the snow cover. The high
bedo of snow adversely affects the
heat balance of a snow-covered re-
region. With 15,834,000 square kilo-
ters of the earth's solid surface cov-
ered by glaciers** and about half as
much again on the sea the influence
of ice on the energy losses of the
planet is enormous.

In 1931 Kalitin (3) made the first
study with modern equipment on the
radiation properties of a snow cover.
This author found albedos ranging
from 52% for an old melting snow
to 88% for a dense fresh snow. Recent data of Eckel and Tams (4)
verify these results fully. They found
50 to 90% energy reflection. Of the
absorbed radiation only very little
penetrates deeper than 10 cm (Kal-
tin, l. c.).

If the reflecting power of a snow or
ice surface is suitably changed a great
amount of energy otherwise irre-
trievably lost is available for mel-
ting the ice or snow. During the winter
seasons 1937/38, 1938/39 and 1939/40
experiments were conducted to mea-
sure the effect of changing the albedo
of ice and snow surfaces. After a
few preliminary tests it was found
that a thin cover of finely powdered
coal (½ mm thick) answered the
purpose very well. The coal dust will
absorb close to 90% of the incident
radiation. In many cases the 80% differ-
ence in albedo between a white
and black surface will be sufficient to
raise the temperature of the snow to
the melting point. Fairly large
patches of snow were covered with
ccoal dust. The melting process in
these patches started much earlier
than in the uncovered parts of the
snow. The surface of the coal-covered
snow becomes criss-crossed with little
channels and the whole snow bed
begins to sag. In case of a thin snow
cover the ground will soon show
through in such a circumstance.

A series of measurements were
made to determine the temperature of
the snow surface in undisturbed state
and immediately under the coal-dust
layer. A typical case is presented in
Table 1. At the beginning of the ex-
periment (9:00 A. M., Dec. 15, 1939)
the temperature of the snow surface
was —6.5°C. The sky was cloudless.
A small patch of snow was covered
with coal dust and the changes can be
seen from the table.

### Table 1. Influence of albedo-change on temperature of snow surface.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dry</td>
<td>Wet</td>
<td>(%)</td>
<td>Covered</td>
<td>Normal</td>
</tr>
<tr>
<td>9:00</td>
<td>—3.5</td>
<td>—5.0</td>
<td>68</td>
<td>—6.5</td>
<td>—</td>
</tr>
<tr>
<td>9:12</td>
<td>—4.4</td>
<td>—6.2</td>
<td>1.8</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>9:20</td>
<td>—4.0</td>
<td>—5.8</td>
<td>1.8</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>9:50</td>
<td>—2.5</td>
<td>—4.3</td>
<td>64</td>
<td>—6.2</td>
<td>—</td>
</tr>
<tr>
<td>10:50</td>
<td>—1.8</td>
<td>—3.7</td>
<td>60</td>
<td>—2.5</td>
<td>2.5</td>
</tr>
</tbody>
</table>

The table indicates that after only
twelve minutes of exposure the tem-
perature of the coal-covered snow
surface was raised by 1.8°C. In one
hour and fifty minutes the tempera-
ture difference between covered and
uncovered snow had risen to 2.5°C.
Moreover, after that interval the cov-
ered snow surface had become 1.8°C
warmer than the air temperature,
which was still below freezing, and
the covered snow started to melt rap-
idly. At that time the coal dust it-
sel had already a temperature of

**According to an estimate of Daly (2) ;
compar with this area the U. S. area of
9,527,250 sq. kms.
+1.3°C but the snow beneath would, of course, stay at 0°C as long as liquid and solid phases were both present. The uncovered snow on that particular day did not reach the melting point until 13:05 when the air temperature was +1.0°C. The factors which kept the surface intact not only include air temperature and radiation intensity but also the evaporation, which, with a fairly low relative humidity and a fresh wind of 16 miles per hour, would be considerable.

As can be seen from Table 1 the solar radiation for that example was quite high but it is not necessary that the sky be clear to produce an effect. Even the slight quantity of diffuse radiation penetrating through a cloud cover will help to melt the snow. Such a case was encountered on Dec. 8, 1938. The air temperature was at 8:15 A. M. —0.1°C, the sky was overcast and a light fog prevailed with a relative humidity of 99%. The snow cover was 1 cm thick. A patch covered with coal dust had melted within two hours, while the air temperature had risen to 0.4°C. The radiation intensity was 0.09 cal/min. cm². At that time the uncovered snow was nearly undisturbed except for some clotting. It took another hour and one-half, with the temperature rising to +1.0°C, the radiation increasing to 0.15 cal/min. cm² to melt the uncovered snow.

Another example is worth citing because it took place on a day with almost no air motion. Under such conditions the radiation phenomena have free play. On January 10, 1940, after a typical radiation night the air temperature at 8:15 A. M. was —11°C, 85% relative humidity. The snow surfaces, both covered and uncovered, had a temperature of —12°C, which also happened to be the minimum reached since the day before. During the night both types of surfaces assumed the same temperature. At 10:30 A. M. the air temperature was —6.4°C, the covered snow surface showed only —2.6°C; uncovered snow in the sun had a temperature of —5.5°C and in the shade —8.5°C. One hour later the air temperature had risen to —2.5°C. A layer of 3 cm snow, that had been covered with coal dust, had melted and the ground beneath it had reached a temperature of —6.6°C.

A number of experiments were carried on with blocks of ice of 55 sq cm surface and 8 to 9 cm thick. These blocks were weighed at given intervals. The weight loss of the blocks covered with coal dust compared to identical control blocks could be observed even if the temperatures were considerably below freezing. Table 2, series A, shows such a set of experiments, with the surface of the blocks in horizontal position.

**Table 2. Weight loss of ice blocks under the influence of radiation**

<table>
<thead>
<tr>
<th>Series</th>
<th>Date</th>
<th>Interval of Exposure</th>
<th>Air Temp. Dry (°C)</th>
<th>Weight Loss of Covered Blocks (Tot.-Control)</th>
<th>Sky</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Dec. 10, '37</td>
<td>4.0 hrs.</td>
<td>—6.5</td>
<td>5.5% 4.1% clear</td>
<td>clear</td>
</tr>
<tr>
<td>A</td>
<td>Dec. 11, '37</td>
<td>1.3 &quot;</td>
<td>—7.5</td>
<td>4.4% 4.1% intermitt. sun</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>Dec. 13, '37</td>
<td>4.5 &quot;</td>
<td>—6.0</td>
<td>4.3% 1.0% cloudy</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Dec. 29, '37</td>
<td>4.5 &quot;</td>
<td>0.0</td>
<td>75.2% 15.2% fair</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Dec. 14, '37</td>
<td>2.0 &quot;</td>
<td>—6.5</td>
<td>37.4% 29.3% clear</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Dec. 14, '37</td>
<td>2.0 &quot;</td>
<td>—5.0</td>
<td>68.8% 53.1% clear</td>
<td></td>
</tr>
</tbody>
</table>
The weight decrease in series A is only rather small. It ranges between a surplus of one to four per cent for the covered blocks compared to the controls. Yet, considering the low temperatures it is still impressive. In the experiment marked B in the table, the mean temperature was 0.0°C and the difference between the covered and uncovered blocks goes up to 15%. The two tests under C were carried on the same day with temperatures nearly as low as those under A. The first group under C taking place in the early forenoon, the second around the noon hours. The difference between series A and C was that in the latter case the blocks were inclined 20° against the horizontal toward the sun. Under such circumstances the radiation effect becomes more pronounced. With an air temperature of —5.0° the covered block lost within two hours 68% of its weight, or 53% more than the similarly exposed control block. For these earlier experiments no simultaneous radiation ob-

servations are available.

A later series of experiments was carried on, for simplicity’s sake, with refrigerator ice blocks, of 10 sq cm surface and 2.5 cm thickness. In 34 cases the solar radiation was measured concurrently. The temperatures were close to freezing point, either slightly below or above. The hourly difference in the percentage weight decrease depended, in an average, upon the radiation intensity, as follows:

<table>
<thead>
<tr>
<th>Radiation intensity (cal/min/cm²)</th>
<th>Surplus of weight decrease of covered blocks over controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4</td>
<td>6%</td>
</tr>
<tr>
<td>0.67</td>
<td>10%</td>
</tr>
<tr>
<td>0.92</td>
<td>14%</td>
</tr>
</tbody>
</table>

This shows not only that the covered blocks melted faster than the controls but that the difference in the melting is nearly proportional to the intensity of the solar radiation.

The measurements of one day shall be cited in Table 3 as a typical example, closely duplicated by the rest of the measurements on other days.

**Table 3. Difference of melting of covered and uncovered ice blocks, Dec. 11, 1939.**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>* 8:20</td>
<td>9°</td>
<td>0.36</td>
<td>—7.5</td>
<td>—8.0</td>
</tr>
<tr>
<td>9:30</td>
<td>19°</td>
<td>0.53</td>
<td>—5.2</td>
<td>—6.1</td>
</tr>
<tr>
<td>10:30</td>
<td>24°</td>
<td>0.32</td>
<td>—4.0</td>
<td>—5.3</td>
</tr>
<tr>
<td>11:30</td>
<td>27°</td>
<td>0.74</td>
<td>—1.5</td>
<td>—3.7</td>
</tr>
<tr>
<td>* 13:05</td>
<td>27°</td>
<td>0.38</td>
<td>+0.5</td>
<td>—3.2</td>
</tr>
<tr>
<td>14:10</td>
<td>21°</td>
<td>0.40</td>
<td>+1.6</td>
<td>—2.4</td>
</tr>
<tr>
<td>* 15:10</td>
<td>14°</td>
<td>0.19</td>
<td>+2.4</td>
<td>—2.2</td>
</tr>
<tr>
<td>16:10</td>
<td>5°</td>
<td>0.02</td>
<td>+2.4</td>
<td>—1.9</td>
</tr>
</tbody>
</table>

In this case the wet-bulb temperature stayed all day long below freezing point and it is likely that the ice assumes a temperature closely approaching it. The uncovered block decreased 9% in weight, mostly through evaporation. The covered block decreased 38.5% in weight, the difference of 29.5% being due to the radiation influence. A thin cloud cover was present all day and the maximum radiation was only 0.75 cal/min. cm². Yet the melting effect is quite remarkable. In fact, the weight measurements do not even tell the whole story. At the times marked by an asterisk in the table the blocks were photographed and the results can be seen in Figure 1. The uncovered block does not show any appre-
FIG. 1. Various stages of melting of covered and uncovered ice blocks.

ciable outward change, whereas the covered cube shows the development of a deep crater. In the last picture, taken at 15:10 the crater was filled with 4 mm depth of water, representing about 2 cc of water. This melted water was weighed with the cube be-

cause the crater prevented it from running off. Actually, therefore, the melting power was about 9% greater than indicated in the table.

The measurements confirm what was said initially. If the albedo of a snow or ice surface is changed toward a greater absorption of incident energy considerable amounts can be gained. It may seem bold to base speculations on small scale experiments such as these. Yet the fact remains that the temperature and radiation conditions of our winter months approximate those of the Arctic summer. The excellent series of radiation measurements made by Goetz (5) during the summer of 1929 in Spitsbergen indicated that in nearly 79° latitude the noon radiation on clear days is around 1.1 cal/min. cm² and at midnight 0.5 cal/min. cm². G. Perl (6) in her general survey of the radiation sums in various latitudes estimates for a horizontal surface in the polar regions the values given in Table 4.

TABLE 4. Daily sums of radiation on horizontal surface in cal/cm² for the 15th of each month, according to Perl.

<table>
<thead>
<tr>
<th>Lat.</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
</tr>
</thead>
<tbody>
<tr>
<td>75°</td>
<td>280</td>
<td>515</td>
<td>637</td>
<td>595</td>
<td>397</td>
<td>155</td>
</tr>
<tr>
<td>90°</td>
<td>155</td>
<td>482</td>
<td>637</td>
<td>610</td>
<td>305</td>
<td>27</td>
</tr>
</tbody>
</table>

If one could change the albedo of the ice surface as in the experiments reported above, and considering a very unfavorable case, namely that cloudiness would cut off 9/10 of the radiation the increase in absorption would still be the extraordinary sum of 256×10⁹ kg/cal per summer per square mile. It is utopian to propose covering large ice fields each spring with dark dust but it would seem to be feasible at least to melt off considerable portions of glaciers. Those glaciers extending with their tongues into the valleys of many mountainous regions have a profound influence on the local climate. Töllner (7) reports that the surface temperature of an Alpine glacier in summer is 6°C below that of surrounding soil. This temperature difference gives rise to the heavy blasts of cold air blowing down the valleys, often reaching velocities of 12 miles per hour and extending 5 to 6 miles into the valley beyond the tip of the glacier. The effects of slighter flows of cold air can be felt down to the mouth of the valley. The cold glacier winds can be observed even on days with clouds and rain. They suppress the ordinary upward directed valley winds. They
play according to Töllner (l. c) an important role in the state of equilibrium of the glacier and can be considered as a condition for the maintenance of the ice, especially near the tongue of the glacier, which might melt unless ventilated by these cold air currents. Besides, these winds produce damages to the vegetation by direct blasting effects of sand and snow carried along. They also depress the line of grass vegetation as much as 1500 feet in elevation (Friedel, 8). This is partly due to the drying effect of the winds. Furthermore, the growing season, already rather short in northern latitudes is even more restricted in valleys with glaciers at their upper end.

Ten to twenty days increase in growing season near the mouth of the glacier valleys could be obtained by eliminating the cold drafts.

*It is reported that experiments have been made in northern Russia to lengthen the growing season by melting off the snow cover sooner in Spring. Also travelers in parts of Tibet report that the natives throw stones on their snow-covered crop fields in Spring to hasten the melting.—R. G. S.

Radio Equipment for an Un-Manned Weather Station*

C. B. PEAR, JR.
Blue Hill Observatory, Milton, Massachusetts

When the Olland System was first devised, it was for the purpose of sending information over telegraph lines from land stations. Later it was sent up in the air with balloon-borne meteorographs to radio reports to the surface; and now it returns to earth to send reports from remote points, also by radio. Such further extension of the application of this useful device has inviting prospects, in its ability to provide reports from points where it would be too difficult or expensive to maintain a manned station. Such points would include mountains, polar stations, islands, and buoys moored in the oceans, and could help fill many gaps in the present network of synoptic reporting stations as well as, perhaps, replace men in certain locations.

Considering the advantages that an automatically-reporting weather station would have, surprisingly little work has been done toward developing a practical system. A display of a tentative design, by Messrs. Diamond, Hinman, and Lapham, some vague reports of work in the U. S. S. R. (1-2), and our small beginning at Elmira in 1936 (3) complete the list that has come to the author's attention. Therefore it seemed worthwhile to make a start in this direction. The