WEATHER OBSERVATIONS DURING 1940–1941 AT LITTLE AMERICA III, ANTARCTICA

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INTRODUCTION

It is with the following aims that this report has been prepared:

1. To provide as complete an explanation as possible of the exact conditions under which the records at Little America III, the West Base, were obtained, for the benefit of any future students of the data.

2. To advise anyone planning further exploration in the same area concerning the difficulties encountered and the precautions to be taken in advance.

3. To act as a general report to the two agencies directly concerned, the United States Weather Bureau and the United States Antarctic Service, on the work accomplished, and to explain to some extent the limitations imposed on the original meteorological program.

Only the West Base activities, and those aboard the U. S. M. S. *North Star*, are discussed here. Herbert G. Dorsey, Jr., the East Base meteorologist, made both the outward and return voyages aboard the U. S. S. *Bear*, and except for a few days together at the Bay of Whales in February, 1940, before the start of their respective programs, and three days in Punta Arenas, Chile, in March, 1941, on the homeward voyages after evacuation of both bases, the two meteorologists did not see each other during the entire period of the expedition.

No attempt has been made to give here any summaries or conclusions based on data obtained; individual reports of some phases of the work are ready for publication, others are in preparation, and it is hoped that a general report of the results of the entire meteorological program can be completed in the not too distant future.

This report was prepared during the fall of 1941 and submitted in typescript to the two agencies. Originally it was not intended for publication. Complete tabular material and other data, including hourly temperatures, pressures, and winds, upper air temperatures, pressures, and winds, and summaries and breakdowns have been submitted to the United States Weather Bureau for separate publication.

The meteorological program of the United States Antarctic Service Expedition 1939–41 was formulated during July and August of 1939 in conferences between officials of the United States Weather Bureau and expedition directors. The Weather Bureau agreed to furnish two meteorologists, complete equipment for two regular stations together with their outposts and trail parties, and certain additional research equipment, and to arrange for a complete program of pilot balloon work at both stations and radiosonde work at one.

Late in July Mr. George Grimminger,[1] Dr. C. C. Clark, assistant chief of the United States Weather Bureau, and Mr. William C. Haines[2] began preparation of the extensive list of equipment considered necessary. All equipment was carefully packed in strong wooden boxes by the Instrument Division of the Weather Bureau, each box being carefully stenciled on all sides with an identifying number preceded by the symbol WB. A careful listing of the exact contents of each box was later of incalculable aid to the observers when they began to set up their stations.

[1] Meteorologist, Byrd Antarctic Expedition II, 1933–35.

[2] Meteorologist, Byrd Antarctic Expedition I, 1928–30, and Byrd Antarctic Expedition II, 1933–35.

In mid-August I was chosen as one of the two meteorologists to accompany the expedition, and within a month the second, Herbert G. Dorsey, Jr., also had been appointed. In conferences with Dr. C. G. Rossby, Research Director, United States Weather Bureau, and with others, the specific work program was outlined, and a memorandum thereon was prepared for Antarctic Service officials. Late in October the two meteorologists reported to expedition authorities in Boston, Massachusetts. On November 15, 1939, I sailed with other expedition members in the U. S. M. S. *North Star* from Boston, while Mr. Dorsey sailed two days later in the second expedition ship, the U. S. S. *Bear*.

SHIPBOARD OBSERVATIONS

As soon as the *North Star* passed Boston Light, marine weather observations were begun, with the use of the ship's adequate instrumental equipment. Some of these reports were filed for radio transmission, and twice while off the United States coast sufficient radio reports were received to permit drawing of maps for the benefit of the ship's officers and expedition personnel on board.

After the ship had been at sea a few days one of the microbarographs[3] was installed in the wheelhouse. Although this instrument was not designed for marine operation, it gave generally satisfactory records. It remained in continuous operation for a year and a half, traveling from the Virginia Capes via New Zealand to Little America, there to remain a year. It never stopped until it had reached the Weather Bureau Office at Boston, Massachusetts, at the expedition's end.

Six-hourly observations had been taken until the *North Star* reached Panama, but in the month-long Pacific crossing, entries were made only at Greenwich midnight. All observations were entered on the standard marine form. Wind velocities were obtained, in general, from the ship's 4-cup Tycos anemometer; directions by gyrocompass. Pressures were obtained from the ship's marine Tycos, with the use of corrections supplied by the Weather Bureau Office at Seattle, Washington.

In addition, a "trail-type" thermometer box, especially designed for the expedition and constructed just prior to departure from Boston, was fitted with maximum and minimum thermometers and mounted amidships so as to be least affected by the ship's roll. Except in extremely rough weather the maximum readings were reasonably accurate. The minimum thermometer, however, was useful only in unusually calm seas.

Weather during the entire voyage was excellent, except that, when a few days off the New Zealand coast, what appeared to be the edge of a tropical hurricane, centered a few hundred miles to the northward, was encountered.

The ship arrived in Wellington, New Zealand, on December 27. During the three-day stay, two visits were made to the main office of the New Zealand Meteorological Service, where various weather problems were discussed with Dr. M. A. F. Barnett, the director. Specifically, arrangements were made to transmit weather reports to New Zealand every 6 hours until the ship was more than 500 miles south of the islands. A copy of the marine weather broadcasting schedule was obtained, and sea-level pressure values, reduced from the hilltop observatory, were obtained for comparison with the readings of instruments aboard the ship.

At noon, December 30, 1939, the *North Star* sailed for Dunedin, southernmost of the four principal cities of New Zealand, where another three days were spent in final alterations of equipment. As there was no weather station at Dunedin, barometric readings were obtained for further check on the barograph and aneroid from a lighthouse 12 miles distant, part of the Dominion's synoptic network.

At 6:00 A. M., January 3, 1940, the *North Star* left Dunedin. During the southward voyage observations were taken every 6 hours and filed for transmission to New Zealand. In addition, all records were brought up to date, preparations were made to begin shore records as soon as unloading started, and help was given both in the preparation of some needed aerial navigation charts and in the general job of preparing to unload the ship.

On January 11 the Ross Ice Barrier was sighted. The ship circled in the Bay of Whales, then headed eastward along the Barrier looking for a more suitable unloading place. After investigating Kainan and Okuma Bays, the ship returned to Kainan Bay early on January 12. Since neither Okuma Bay nor Kainan Bay appeared as suitable as the Bay of Whales for unloading operations, the *North Star* returned to that point and unloading immediately began.

[3] Four-day, $2\frac{1}{2}$ to 1 scale, with 2 dash pots, manufactured by J. P. Friez & Sons, Baltimore.

Shipboard weather observations for the remainder of the *North Star*'s extensive trip were entrusted to Eric T. Clarke, physicist in charge of cosmic-ray equipment for the Bartol Research Foundation, of Swarthmore, Pa. Records which he obtained in co-operation with the ship's officers are a valuable addition to the rather meager fund of information on the weather of the extreme southern Pacific.

From the Bay of Whales the *North Star* sailed northwestward to traverse the pack ice in the same longitude where she had entered, then proceeded east-northeast directly to Valparaiso, Chile, on one of the few such diagonal crossings on record.

The *Bear* reached the Bay of Whales two days after the *North Star*. Within four days, having completed discharging its limited cargo of supplies, the ship, with Admiral Byrd on board, departed on a short trip of exploration to eastward. Returning for three days early in February, the *Bear* then sailed on February 4 for Marguerite Bay, Palmer Peninsula, some 1,600 miles east-northeast of the Bay of Whales. At Marguerite Bay a rendezvous was kept with the *North Star*, just arrived from Valparaiso with the supplies and equipment for East Base. When a site was determined on, the ships mutually aided in establishing the base. They then departed on separate courses on the return voyage to the United States.

On January 10, 1941, the *Bear* returned to the Bay of Whales, and evacuation of West Base was started. Two weeks later the *North Star* arrived, exactly one year after her departure.

On February 1 the two ships sailed from the Bay of Whales and proceeded independently toward Marguerite Bay to evacuate the East Base. Traveling several hundred miles apart along the Antarctic Circle, the ships obtained records of potentially great value in studying the storms of these perpetually cloudy regions.

Each ship carried one of the microbarographs from Little America. In addition, the hygrothermograph was operated on the top deck of the *North Star*, where 6-hourly observations were taken to supplement the hourly entries in the ships' logs.

The marine barometer used as a check instrument at West Base was installed on the *North Star*'s bridge, and readings were made at least once a day, at Greenwich midnight. Since the ship's thermometers did not register below 20° F., a psychrometer was mounted on the wing of the bridge for use of the officers in their hourly readings. A second psychrometer was whirled on the top deck near the hygrothermograph at the 6-hourly observations.

During the 17 days of the *North Star*'s stay, observations were taken in the land form rather than the marine, and they were transmitted to East Base for relay to South America, where East Base reports were being sent regularly. The major work of the observer, however, was the erection and maintenance of a tide gauge to determine (for the first time, so far as was known) the amplitude, and especially the times, of the tides in this section of the world.

The gauge was simply a long 1″ × 4″ board on which were marked 10-centimeter intervals. The erection of the stick proved rather difficult because of the rocky, steep-sided shore. Even though braced by rocks below the low-water mark and guyed by ropes to the shore, it was threatened several times by drifting ice. The gauge was mounted directly astern so that the ship's searchlight could be turned upon it for night-time readings. Through the captain's cooperation, the readings were made hourly by the seaman on watch.

Rather complete records over a 10-day period showed the tide to be of the same general pattern as at Cape Horn, with equal maxima and minima only at the times of new and full moon. The amplitude was less than 1.5 meters, as was to be expected, but the times of high and low tide were one or two hours earlier than at Cape Horn, although the station was considerably farther to the east.[4]

On March 25 the *North Star* arrived at Punta Arenas. During the 8-day stay in that southernmost city, comparisons were made between the marine barometer, the West Base station barometer, and the official barometer at the Chilean naval station. Various meteorological problems were discussed with Señor U. Mattassi, air force meteorologist for the air base and for the projected government airline to Punta Arenas.

The *Bear*, with the evacuated East Base men on board, arrived at Punta Arenas on March 28. On April 2 both ships departed: the *Bear* for Buenos Aires, Rio de Janeiro, and Boston; the *North Star* for Valparaiso, Panama, and Seattle.

On May 12, 1941, I reached Washington to begin compilation of the data obtained and preparation of various reports.

[4] All tidal data thus obtained have since been furnished the Navy Department.

SURFACE OBSERVATIONS

The *North Star* began unloading operations early on Saturday, January 13, 1940. By noon a temporary weather station was set up on top of the barrier. At first the station included only the "trail-type" thermometer box, which had been in use aboard ship, and a hand anemometer mounted on a stick. Weather notes, including instrumental readings, were made whenever feasible, since the observer was assisting with unloading operations.

By January 24 a more elaborate station had been established, including in its equipment a cotton-region thermometer shelter with maximum, minimum, and current thermometers, a standard 3-cup anemometer on a 6-foot pole, and the hand anemometer. On this day the microbarograph was removed from the ship's bridge and placed in the shelter; alongside it was installed a hygrothermograph.

Upon the departure of the *North Star* at 4 P. M. on January 24, "ice party" personnel, who had been living aboard ship, moved 2 miles inland to the future camp site and pitched tents. The following morning erection bagan at this site of a weather station, similar to that at the barrier cache. A second cotton-region type thermometer shelter was set up to house maximum, minimum, and current thermometers, a second microbarograph and a standard thermograph. Nearby a mercurial barometer was mounted inside a copper-shielded barometer board which had been fastened to a length of 2″ × 4″ lumber fixed upright in the snow. A standard 3-cup anemometer was mounted on a brass rod 6 feet above the snow, to measure wind passage, and a hand anemometer was available for velocity determinations. In a few days an 18-foot wind tower was erected and a third anemometer was placed on the cross-arm (fig. 2). It was not considered advisable to install the triple register outdoors, and therefore automatic wind records did not begin for two months more.

FIG. 1. First weather station at main camp, Little America III, during first week of operation. View to WNW; cook tent at right. (Official U. S. A. S. photo.)

FIG. 2. Taking the observation. The shelter holds maximum, minimum, and current thermometers, and a thermograph. Temporary location, view to south; partly-completed "science building" at left. (Official U. S. A. S. photo.)

Observations were begun at the camp site at noon, January 25 (0000 GMT January 26), and continued irregularly until March 1, when a program of 6-hourly observations was initiated. This program was continued without a break until closing of the camp 11 months later.

For the first five weeks an effort was made to obtain as many observations as possible on the international hours of 0, 6, 12, and 18, Greenwich Meridian Time. However, many entries were made at intermediate hours, since the observer was working full time in helping to transport freight and build camp, and therefore had to take observations and set up his station largely "on his own time."

By enlisting the aid of two of the camp personnel, observations also were obtained from the barrier cache station. This station, whose equipment was similar to that at the camp site, was discontinued on February 15.

All observations for the entire year were kept at Greenwich Meridian Time. Since the camp was located at longitude 164° W. and kept 180th (west) meridian time, observations were just half a day ahead of "local" time. This led to some confusion among camp members but was nevertheless adhered to, not only because the local time was more than an hour late, but chiefly because other records, such as radio, magnetic, and cosmic-ray, were likewise kept at Greenwich time. This made it convenient to change all record sheets at Greenwich midnight, thus keeping barograms, thermograms, and anemograms separated by months, and thereby eliminating overlaps such as occur when sheets are changed at 8 A. M. or 12 M. (noon).

Once observations were put on a routine basis, they were always taken in the 20-minute period beginning 15 minutes before the hour. Customary procedure was for the observer to reach the thermometer shelter about 10 minutes before the hour, noting cloud amount and type on the way. Returning to the office, he entered the observation, noted wind velocity and direction, then read the barometer, as close to the exact hour as possible.

After March 3 full time was devoted to observations (daily pilot balloon ascents were begun early in February—see next section), computation of barometric and other tables, caring for equipment, and work incident to setting up the complete weather station.

The site originally selected for all instruments was north-northwest of the camp buildings, which were just then being erected. It was as close as possible to the future science building, yet far enough away so that little drifting snow was anticipated, if the immediate area could be kept clear. However, since it lay near the trails leading from the barrier cache, it was impossible to fulfill the good intentions of the camp leader, and soon boxes had been stacked a dozen feet to the east of the wind pole.

On March 12, during a severe storm, a long dune, higher than the thermometer shelter and just 5 feet north of it, was built up by snow dropped behind the near-by boxes by the strong southeast wind. The next day, as soon as the wind abated, shelter No. 1, unused since discontinuance of the barrier station a month earlier, was set up in a level space 20 feet south of the anemometer pole, and instruments were transferred there (fig. 2).

The wind tower itself had not been materially affected by the dune. The new location, however, was still to leeward of camp buildings, and thus it was decided, eventually, to move all outside instruments to the opposite side of the camp.

On April 3 the wind tower was dismounted and moved to a new site 100 feet south of the east end of the main building. The 18-foot pole was erected full height above the snow, and the three guys were anchored to deadmen (2-foot square boards buried a foot in the snow).

When the tower was erected, a spare anemometer cross-arm was placed just below and opposite the regular anemometer support, and a small louvered box, 18 inches on a side, was lashed beneath it (fig. 3). In the box was set a telethermoscope[5] bulb, one of three to be used in study of

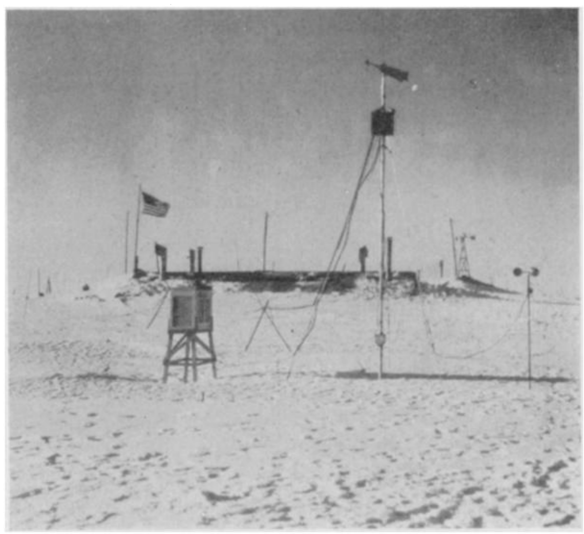

FIG. 3. United States Weather Bureau station at Little America III as operated from May 21, 1940, to February 1, 1941. View from approximately due south. (Official U. S. A. S. photo.)

vertical temperature gradients. Another bulb was to be in the thermometer shelter, and a third in the near-by snow. Wires from the wind instruments and the telethermoscopes were carried over crossed bamboo poles to the corner of the bunkhouse, and thence inside the tunnel system to the office. One of the telethermoscope bulbs was in the box on a pole, another in the shelter, and a third was buried in the snow near the shelter. The lower anemometer, at a height of 2 meters, was connected to a "sunshine" pen of triple register. The upper anemometer (partly hidden behind the box in fig. 3) was at the standard height of 5 meters.

In all, the program called for 16 wires between

[5] Electric resistance thermometer, read by a potentiometer calibrated in Fahrenheit; made by Leeds and Northrup, Philadelphia.

FIG. 4. Light drift caused by a mild blizzard. Cirrus clouds are barely moving. Surface wind is southeast, about 20 miles per hour. (Official U. S. A. S. photo.)

tower and office some 250 feet away: 7 wires for 3 telethermoscopes, 5 for wind directions, and 2 each for 2 anemometers, since it was desired to use blinkers as well as continuous record.

Several lengths of old telephone wire were used to wire the various instruments as far as a master contact board mounted just below the upper anemometer. From there two lengths of 7-conductor cable and one of 2-conductor were carried on crossed bamboo poles above the surface to a second contact board in the camp tunnel system near the main building. Thence the circuits were carried by bare copper wire run through spreaders down the tunnels and through the walls into the weather office, where a third contact board was installed. Because of this involved wiring, there were occasional shorts or breaks in the circuits, but, on the whole, the triple register worked satisfactorily. It was impossible, however, to obtain any reliable readings on the telethermoscope (see section on research problems).

With the triple register wired and the office at last usable, attention was turned first to the pilot balloon program, which had been somewhat neglected. The canvas-walled balloon house, built by the carpenter force, was completed and placed in use, along with the observatory (see next section). Then the radiosonde receiver was set up and adjusted, and daily soundings were begun (see section on radiosonde).

Thus by the end of April the station was doing all the routine work originally planned.

Maintenance of equipment took more than the usual amount of time. Anemometers were changed every two weeks, so that, with two in operation and one spare, there was one change to be made each week. In turn, each of the three "froze" in the course of a couple of months, requiring dressing down the spindle on a lathe. The trouble was due to extreme cold, which caused greater contraction of the brass upper bearing than of the steel spindle. Further trouble due to the difference in thermal expansion coefficients of brass and steel was encountered also in the thermograph clock, which refused to run at −50° F. and colder. Thermograph records, therefore, became intermittent in May and ceased entirely in June, not to be resumed until September.

Largely because of the great temperature range, thermometer breakage was rather extensive. In all, more than half a dozen maximum thermometers broke cleanly at the 62° mark, the center one of the four points at which they are calibrated. On others, bulbs were shattered with temperatures around the freezing point of mercury, −38° F.

At lower temperatures, maximum readings were obtained from special thallium-mercury alloy thermometers provided for testing by the Taylor Instrument Companies, of Rochester, N. Y. Freezing point of this alloy was −60° F. Time had not allowed calibration of these thermometers before the expedition's departure, so an attempt to calibrate was made in the field.

Unfortunately for this program, it was not realized that regular Weather Bureau maximum thermometers are not calibrated at all below freezing, there being technical difficulties which

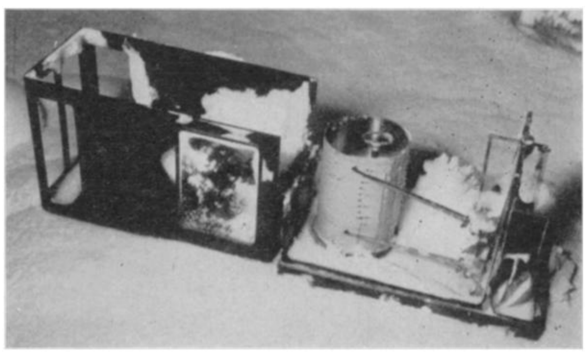

FIG. 5. Hygrothermograph packed with snow after an average blizzard. Loosely fitting case permits snow infiltration. The most imperative improvement in equipment designed for Antarctic work is indicated here. (Photograph by Charles Shirley, U. S. A. S. photographer.)

the laboratory has not yet overcome. In the absence of any corrections on the standard card furnished with each thermometer, it was assumed the instruments were correct to 0.1° F., and corrections for the alloy thermometer were based on that premise.

At temperatures below −35° F., readings of the alloy maximum thermometer were made provisionally and corrected later by means of a curve deduced from the set maximum readings noted at each observation. These readings were compared with the current temperature as indicated by the alcohol minimum thermometers, for which corrections had been supplied. Thus, while recorded temperatures above −35° F. are based on the usual instrumental procedure of three independent thermometers, those below that point are based solely on readings of one alcohol minimum thermometer, as corrected.

To obviate the possibility of this thermometer straying too far from true values, a second minimum thermometer was mounted atop the shelter crossboard so that it could be reset if desired. At temperatures below −60° F. both thermometers were read, and even with application of the indicated correction, the "check" was usually about one degree lower.

At best, alcohol is much inferior to mercury for thermometric use, owing largely to its tendency to vaporize and then condense upon the tube walls. When the bore is made sufficiently large to accommodate a minimum index, this trouble is increased, with the result that readings of current and minimum temperatures on an ordinary minimum thermometer are, at very low temperatures, accurate to no more than a whole degree.

Mercury-thallium alloy, used in the special maximum thermometers, appears much more desirable, and "current" thermometers using this metal would be greatly desirable at all stations where temperatures below −35° F. are anticipated. However, even these thermometers would become inoperative at −60° F.

Owing to the difficulty of obtaining any glass-tube thermometer readings under adverse temperature conditions and of maintaining operation of thermographs in regions of extreme cold and heavy drifting snow (*cf.* fig. 5), it is strongly urged that any future meteorological work in the Antarctic, or under conditions similar to those encountered in the Antarctic, use remote recording electric thermometers. Such instruments, be they of the thermocouple or the resistance type, should be completely wired in advance to heavy rubber-sheathed cables carrying the necessary number of wires and at least 300 feet long to permit installation at a good distance from the camp buildings and with no connections to be completed outside.

As check, mercury or mercury-alloy thermometers could be read once or twice a day. However, an electrical instrument, if continuously recording, would eliminate need for maximum and minimum thermometers except as a stand-by in case of instrument failure and during the first weeks before the more elaborate electrical installation is made.

The desirability of such electrical thermometers was indicated by Mr. Grimminger, but since no such equipment was then in use by the Weather Bureau, none was provided. Any future Antarctic expedition must have well-constructed, reliable, easily installed electrical thermometers if it is to benefit at all by the experience of previous expeditions and if it is to lay any claim to superiority over its predecessors.

Wet-bulb temperatures below the freezing point of water generally are difficult to obtain and are at best a very poor indication of humidity. Even at a temperature of 0° F. a difference of 0.2° in the wet-bulb depression alters the humidity by 7 per cent or more, and at −30° F. relative humidity of 20 per cent yields a wet-bulb depression of only 0.5° F. It is generally futile, therefore, to attempt atmospheric humidity measurements at low temperatures by this standard method. Therefore, except for a trial period in February 1940, no psychrometric determinations were obtained.

When warming temperatures again permitted operation of a clock mechanism outdoors, the hygrothermograph was placed in operation. The traces of this instrument provide the only humidity record obtained. Although the exact behavior of hair hygrographs at subfreezing temperatures is still a matter of experiment, the readings obtained are probably as accurate as can be expected.

No attempt whatever was made to measure precipitation, but extensive measurements were made of surface accretion.[6] Eight long sticks, on which 10-centimeter intervals were marked, were erected in pairs in four directions from the

[6] Readings and recordings of surface accretion were made by F. Alton Wade, senior scientist, U. S. Antarctic Service, who formulated the program and prepared and erected the sticks.

camp. Daily readings of these sticks showed the annual increase in the level of the surface to be about 40 centimeters. Apparently this slow annual increment is compensated by an equivalent melting at the bottom of the tremendous ice sheet so that its general elevation remains sensibly constant throughout the years.

Because of this general accretion the surface level around the wind tower and instrument shelter rose slowly, so that 10 months after its erection the effective height of the wind tower had decreased by some 2 feet. On August 2 the area around the shelter and wind tower was leveled off to remove irregularities caused by eddies around the shelter. On December 9 the average level of the surface was 18 inches higher than at the time of its erection, so the shelter was excavated and re-erected (fig. 6).

FIG. 6. Final instrument exposure, view to northeast (anemometer arm points due north). Altocumulus clouds of type seen are common. (Official U. S. A. S. photo.)

At this final installation the shelter was faced southeast, this being considered the most desirable orientation. With continuous sunlight, considerable difficulty had been experienced in shielding thermometers from direct sunlight at the 1800 GMT (7 A. M. local) observation, when the shelter faced due east. Facing of the shelter southeast prevented sunlight from affecting the thermometers at either the 1200 GMT or 1800 GMT observations, and also preserved the advantage of minimum discomfort to the observer during blizzards.

In the Antarctic even the technique of reading thermometers must be altered. Heat from an observer's body or even the rays of a flashlight cause a mercury column to rise visibly at low temperatures. Thus it is necessary to read thermometers "backwards": tenths are estimated first, then the unit degrees, and finally the tens of degrees. In general, the current temperature was read as soon as the shelter door was opened, then the maximum and minimum thermometers.

All Weather Bureau rules and definitions were closely followed in making the observations, except that special definitions were given to certain numbers for "present weather" (ww) in the International Synoptic code dealing with fog, haze, snow, and especially drifting and blowing snow.

Thus there was adopted the critical limit of visibility less than 1/8 mile for 36 and 38, "heavy drift." In addition the distinction between high and low was based on the amount of sky discernible, "low drift," 36 and 37, occurring when at least half of the sky was clearly visible. With more than half the sky obscured, the cloud amount was unknown and drift was called "high," 38 and 39.

Concurrent with this definition, the limits on 75 and 76, heavy snow, were lowered to less than 1/8 mile also. For very light blowing snow, with visibility more than 5/8 mile, the definition of no. 18 (normally "dust storm, visibility over 1,100 yds.") was expanded to include snow.

Table 1, copied from one in constant use by the observers, clarifies the revisions and expansions of the standard ww definitions.

A further special definition was given to 40 (normally "fog") to identify the peculiar "milky"

TABLE 1

UNITED STATES WEATHER BUREAU
LITTLE AMERICA III
WEATHER OBSERVATION CRITERIA

V	Distance limits	Reported as	Range for ww		
			Drift	Snow	Fog
0	under 150′	0	37, 39	75, 76	
1	150′–1/8 mi.	1/35, 1/16			41, 49
2	1/8–5/16	1/8, 1/5, 1/4	36, 38	73, 74	
3	5/16–5/8	5/16, 1/2			
4	5/8–1 1/4	5/8, 3/4, 1			08
5	1 1/4–2 1/2	1 1/4, 1 1/2, 2	18	71, 72	40, 05
6	2 1/2–6	2 1/2, 3, 4, 5			
7	6–12	6, 8, 10			
8	12–30	15, 20, 25			
9	over 30	30, 50			

With *less than half* of sky obscured, drift is *low: 36, 38*
With *more than half* of sky obscured, drift is *high: 37, 39*

condition often encountered in the Antarctic. Uniform stratus cover of considerable thickness so diffuses sunlight that shadows are wholly lacking and perception of distance, or even of relative elevations at one's feet, becomes impossible.

Few natural landmarks were available for visibility measurements. On very clear days Roosevelt Island, more than 30 miles to the southeast, was a good criterion. West Cape, four miles away, provided a fair visibility range, and various other formations of the Bay of Whales, still closer, were tabulated and used. In the camp area itself there were antenna poles, boxes, and buildings which were used to estimate visibility. Blowing snow was somewhat worse around buildings (fig. 4) than in the open, but visibility was strictly dependent on the height of the eye above the surface.

At night, however, these criteria were not available except for the Snow Cruiser, the brightness of whose light at 600 feet gave a very rough indication of the transparency of the atmosphere. Therefore, in May, June, and July visibility values of more than 1 mile are purely arbitrary and have little significance.

Ceilings were measured occasionally by pilot balloons and sometimes inferred from radiosonde observations, but on the whole values assigned were quite arbitrary. Had a standard ceiling light and clinometer been provided, they probably would have been used, and it is recommended that any future Antarctic expedition include modern ceiling measuring equipment.

Packing of surplus equipment began in December 1940. The *Bear* arrived on January 10, 1941, and within a week all equipment not needed in the current program was packed. On

TABLE 2

West Base, Surface Air Temperature, Fahrenheit, 1940–41
Daily Values (mean of daily maximum and minimum)

Date	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	15.4	−7.2	25.3	−38.2	−57.0	−20.0	−30.0	−67.3	3.9	−9.2	10.1	30.8
2	11.4	0.0	14.5	−43.0	−27.5	−7.6	−17.8	−65.2	−0.5	−2.2	10.3	28.9
3	15.8	−1.0	0.1	−35.8	−37.3	3.3	−41.8	−70.2	−21.2	−7.9	12.3	21.3
4	9.8	3.4	4.1	−34.1	−27.1	8.0	−52.6	−60.1	−11.7	−9.5	21.1	23.4
5	7.1	8.0	4.6	−33.7	−34.7	−4.0	−51.4	−69.2	−14.4	−2.3	22.6	18.8
6	6.8	9.3	0.0	−54.5	−57.4	−17.6	−29.0	−68.0	−18.5	0.5	26.4	22.1
7	3.7	−17.1	−6.4	−53.2	−39.8	−32.1	−20.3	−56.4	−9.3	4.6	25.2	21.4
8	10.0	−7.2	−40.0	−42.7	−19.1	−33.6	−22.0	−64.5	−33.4	10.8	20.9	17.4
9	3.7	−6.2	−39.0	−45.1	−9.1	−16.3	−45.3	−49.7	−38.1	15.0	15.2	16.2
10	9.8	−10.2	−38.0	−56.3	−29.3	−45.2	−23.8	−54.5	−25.7	13.1	11.0	13.0
11	6.6	10.1	−43.5	−54.4	−29.3	−26.9	−13.8	−52.3	−8.3	14.1	13.2	15.5
12	12.4	19.6	−39.6	−39.3	−9.2	−35.1	−16.5	−33.5	−22.6	10.5	14.0	15.8
13	4.2	22.9	−48.0	−42.0	−31.4	−47.2	−29.4	−26.9	−18.8	−3.0	11.4	21.7
14	7.0	25.0	−37.8	−54.1	−7.8	−49.8	−31.8	−41.5	7.8	0.5	8.9	16.7
15	17.7	24.9	−15.2	−59.1	−3.8	−50.6	−32.0	−58.1	7.1	9.6	12.4	13.6
16	11.9	28.6	−18.0	−49.0	−26.6	−64.3	−26.4	−59.1	−8.2	5.5	13.3	14.8
17	5.6	20.0	−0.1	−25.4	−35.7	−48.3	−41.8	−51.8	−20.8	12.2	11.1	9.5
18	−4.7	21.8	16.4	12.6	−54.2	−59.5	−29.9	−61.6	−15.3	15.7	13.8	12.1
19	6.1	19.3	2.1	8.1	−53.4	−56.9	−7.3	−57.2	−9.0	14.4	22.4	13.4
20	14.5	−2.2	−7.6	1.3	−45.0	−44.4	−16.6	−51.0	−2.3	10.0	23.2	17.5
21	9.8	−21.2	−17.4	−11.2	−17.7	−35.2	−19.1	−60.0	7.4	8.6	30.5	15.5
22	14.2	−4.3	−17.3	−27.0	−5.0	−20.6	−40.0	−49.0	−2.1	8.5	22.0	18.4
23	23.1	7.0	−5.5	−25.7	−8.7	−30.0	−18.6	−21.1	−14.6	5.8	13.4	23.3
24	15.1	−2.9	−9.4	−38.4	−13.0	−29.1	−11.6	−1.1	−17.0	6.6	23.0	16.6
25	17.9	−9.3	−22.5	−38.3	−5.8	−25.5	−41.8	−10.8	−19.5	6.9	23.8	13.9
26	19.1	12.4	−9.2	−17.2	−6.6	−13.9	−49.8	−17.9	−16.8	4.9	23.7	16.2
27	8.1	−25.1	−7.6	1.0	−9.7	−16.5	−46.3	−16.8	−7.6	5.4	30.8	20.4
28	3.2	−17.8	−8.0	−17.7	−8.3	−4.0	−29.7	−11.3	−10.9	13.0	30.7	11.3
29	8.3	−9.4	−5.4	−17.7	−24.4	−6.3	−40.7	3.6	6.3	11.8	26.7	4.3
30	....	−8.0	−19.4	−34.7	−24.5	0.4	−57.5	8.0	−1.3	13.1	27.8	14.0
31	....	16.4	....	−34.6	....	−10.0	−64.9	....	−5.7	....	30.6	16.6
Mean	10.1	3.2	−12.9	−32.3	−25.3	−27.0	−32.2	−43.2	−11.0	6.2	19.4	17.2

TABLE 3

West Base, Surface Wind: Prevailing Direction and Mean Velocity, by Days, 1940–41

(Velocities corrected to true value, miles per hour)

Date	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	S 9.3	SE 10.5	NE 31.3	S 3.1	SW 5.3	S 10.1	SW 13.2	E 3.9	E 19.8	S 10.8	E 16.2	N 9.2
2	SW 8.8	SE 11.8	NE 21.8	E 3.4	N 8.4	NW 12.2	SW 8.2	S 9.4	E 18.4	E 12.4	SE 28.8	E 16.1
3	E 4.3	SE 14.0	E 13.9	SW 4.1	S 6.2	NE 26.6	E 6.7	S 6.0	S 11.3	SW 10.0	E 28.3	E 11.3
4	SE 15.4	S 8.0	E 9.2	SE 8.6	N 12.9	E 11.7	S 7.2	S 9.8	W 17.2	S 8.5	E 21.4	SE 10.9
5	S 6.8	SE 13.2	E 11.9	S 7.5	E 13.0	N 5.6	S 7.4	SW 5.2	W 11.9	S 13.7	E 18.1	SE 8.2
6	E 23.4	E 13.8	SE 16.2	S 4.6	SW 8.2	S 7.4	S 7.2	S 7.0	S 4.0	SW 19.8	E 13.3	S 6.1
7	S 8.9	SW 11.5	SW 17.9	S 4.5	E 10.4	S 8.4	N 11.8	SW 9.4	E 11.6	E 15.9	S 5.4	S 9.3
8	S 7.3	E 14.2	SW 8.5	SW 9.9	E 32.9	SW 7.6	E 14.0	S 7.2	S 13.1	E 15.6	S 5.7	SW 11.1
9	S 12.5	W 9.2	S 9.2	E 20.8	E 20.2	N 14.0	S 8.7	E 7.1	S 7.1	E 5.4	SW 7.5	S 6.3
10	S 10.2	SE 13.8	SE 6.5	S 6.2	W 8.2	SW 8.6	E 22.9	SW 8.0	E 13.3	S 4.3	S 6.5	E 14.0
11	E 11.7	E 26.1	SW 5.3	E 9.0	E 24.6	E 16.7	E 15.4	E 9.5	SE 26.5	E 8.5	E 10.6	E 10.0
12	S 10.8	E 28.5	S 9.7	E 9.4	E 22.4	S 6.2	S 9.0	E 18.4	S 14.0	SW 8.9	S 6.5	SW 6.8
13	E 7.0	NE 14.8	S 5.4	S 4.8	W 10.0	E 7.2	W 7.2	E 17.7	E 11.3	SW 10.8	S 5.8	SW 7.0
14	E 12.4	N 14.0	E 6.4	S 6.4	SE 34.6	S 5.0	S 10.6	S 8.8	E 25.5	E 14.9	SE 11.4	SE 14.7
15	E 9.2	E 24.0	E 9.7	SE 5.1	S 17.6	E 11.0	E 8.7	S 9.5	N 12.8	E 13.9	SE 11.5	SE 16.7
16	S 7.8	N 14.2	SW 10.8	SE 11.8	S 15.4	S 6.9	E 12.4	S 5.6	S 11.8	S 6.4	S 6.8	SE 10.8
17	S 12.2	NW 12.2	E 17.6	SE 34.1	S 11.4	S 10.0	E 6.9	S 8.8	SW 8.4	E 4.4	S 8.2	S 7.9
18	SW 9.0	E 15.8	E 22.9	E 21.6	S 4.0	S 4.6	S 10.6	E 7.2	SW 19.2	E 5.9	SW 8.9	SE 8.0
19	E 3.8	E 9.2	E 15.2	W 13.4	S 7.2	S 5.2	NW 11.5	E 8.0	SW 6.4	NE 8.7	NE 7.2	S 9.1
20	S 6.2	SW 15.2	SE 7.1	W 11.0	SW 8.2	S 6.7	N 21.3	S 7.6	E 14.2	NE 10.4	E 14.8	E 10.7
21	E 12.0	SW 6.5	SW 3.7	E 9.3	E 19.3	E 6.8	SE 20.1	SW 4.2	E 17.7	SW 10.9	N 10.1	E 8.8
22	E 14.0	E 11.5	E 3.8	SW 5.8	E 15.9	E 9.8	SW 15.4	W 5.5	E 17.7	SE 10.4	S 13.0	SE 6.6
23	E 9.0	SE 21.3	E 6.3	N 6.3	E 17.6	SW 4.1	E 30.2	SE 35.4	E 9.2	S 14.7	SW 8.2	E 11.5
24	SW 10.7	E 10.2	E 22.7	S 6.1	E 14.0	E 7.8	E 19.7	N 30.1	S 10.2	E 7.0	E 5.7	S 15.4
25	NW 7.5	S 20.0	S 20.1	E 10.8	E 23.0	SE 22.1	SW 18.5	N 16.0	S 6.4	E 10.2	E 11.9	S 16.9
26	SE 19.5	E 19.5	S 12.7	E 30.6	E 23.0	S 21.1	SW 7.1	E 13.6	S 8.8	E 15.0	E 25.0	SE 14.2
27	SW 5.2	SW 10.2	S 9.6	E 23.5	E 18.8	E 23.5	SW 9.3	E 13.7	S 19.7	E 20.5	NE 6.8	E 13.7
28	S 6.4	S 12.0	SW 7.5	E 11.5	SW 16.1	E 22.0	E 9.2	E 20.5	E 14.1	E 18.0	N 11.2	S 10.2
29	SE 15.4	S 15.3	E 11.9	SW 15.6	SE 11.0	E 12.4	S 9.4	N 11.8	E 10.4	W 10.8	S 11.0	SW 6.8
30	....	SE 23.8	S 3.1	E 12.6	S 8.0	E 9.2	S 4.2	E 18.4	SE 18.5	NE 7.3	W 9.8	SE 14.3
31	....	NE 20.9	....	E 9.5	....	S 17.6	SW 5.8	....	E 11.7	....	N 5.1	E 22.1
Mean	S 10.2	SE 15.0	E 11.9	S 11.0	E 14.9	E 11.3	S 11.9	E 11.5	E 13.7	E 11.1	E 11.6	E 11.1

January 15 the last radiosonde ascent was made and the equipment torn down and packed. On January 29 the last pilot balloon ascent was made.

After the 0000 GMT observation on February 1, the triple register, barometer board, and other instruments were packed. Anemometers, wind vane and bearing, and wind-vane contacts were removed from the pole, which was left in place. The shelter was taken down and stored in the vacant office together with the spare shelter, a number of surplus balloons of all sizes, lanterns, and miscellaneous equipment.

Barograph and thermograph were kept in operation at the base until a few moments before the camp was finally closed and sealed. These instruments were carried to the ship personally by the observer, who also carried the station barometer in a leather case on this last trip from West Base, Little America III.

PILOT BALLOONS

On January 28, 1940, four days after departure of the U. S. M. S. *North Star*, the first pilot balloon ascent of the United States Antarctic Service was made. This 100-gram balloon attained an altitude of 15,700 meters, higher than any pilot balloon ascent ever made on the Antarctic Continent previously.

Other ascents were made as opportunity afforded until a regular program of daily soundings was inaugurated on February 12. Thereafter and until January 29, 1941, soundings were made daily unless prevented by drifting snow or rendered inadvisable because of low visibility.

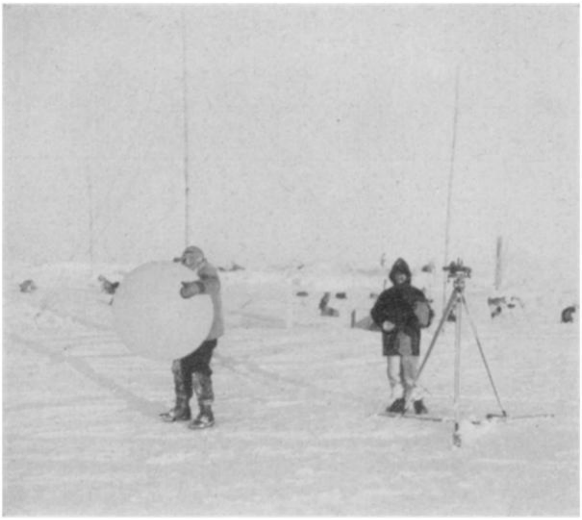

FIG. 7. A pilot balloon ascent from the snow surface. (Official U. S. A. S. photo.)

Sometimes, lack of time of the observer or lack of assistance prevented runs from being made. In a few instances more than one run was made in a day, either to provide reports of winds aloft for pilots or to study conditions peculiar to the day.

Until late March these observations were made from an improvised site on the level snow surface (fig. 7), the theodolite (fig. 8) being moved twice as building construction and snow drifts required. These three initial locations were approximately 100 feet or 30 meters above sea-level. During this period 39 ascents were made. For the first few weeks balloons were inflated in the open. Later equipment was moved inside the abandoned cook tent, about 400 feet from the theodolite location. Many camp members assisted in the observations by recording: with two men, each could keep his hands covered most of each minute and thus avoid discomfort, but on solo observations fingers became quite chilled. One run was stopped after 30 minutes on account of frostbite.

Early in April a combination inflation house and observatory was completed at one end of the science building and on April 14 the first ascension was made from this new observatory, approximately 33 meters above sea-level.

Two smoke pipes and a few antenna poles in the immediate area prevented the location from being ideal, but none of these obstructions was ever a serious handicap during a pilot balloon ascent. Of much greater concern were smoke and vapor. While smoke trouble could be largely eliminated by advance banking of the stoves and through cooperation of others, there was no way to shut off the clouds of vapor which arose on cold days, and these greatly limited the nocturnal observations.

The 12-foot-square inflation room was floored 5 feet above the snow surface, leaving a space 10 feet high in which balloons could be inflated. A ladder gave ready access to the inflation room floor and to the observatory deck 5 feet higher. Beneath the inflation room floor were stored most of the 134 hydrogen cylinders. After inflation and tying, pilot balloons were handed up to the observer, who released them through the theodolite hatchway as soon as the assistant returned to the telephone inside the building. In general, the design of this 2-level inflation room proved highly satisfactory. However, drift snow always leaked in during blizzards, and much time was spent in clearing the accumulated snow.

Considerable leakage of hydrogen cylinders was experienced, the chief difficulty being failure of the valves to close completely once a cylinder had been tapped.

With the disappearance of the sun at the onset of the 4-months winter night on April 22, the use of standard candles and lanterns for darkness flights was begun (fig. 9). Difficulties arose at once, and several weeks elapsed before many of these were eliminated. Melting of wax was insufficient to hold candles to lanterns, T-pins proving far more suitable for this purpose. Heating the candles until the actual moment of

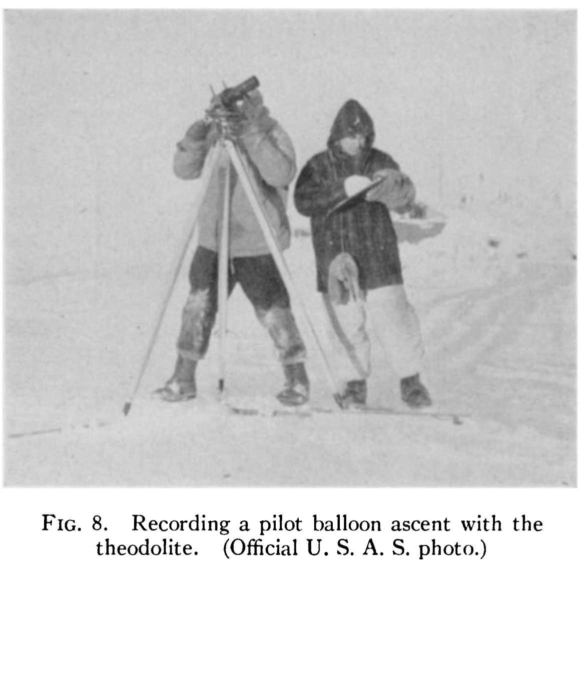

FIG. 8. Recording a pilot balloon ascent with the theodolite. (Official U. S. A. S. photo.)

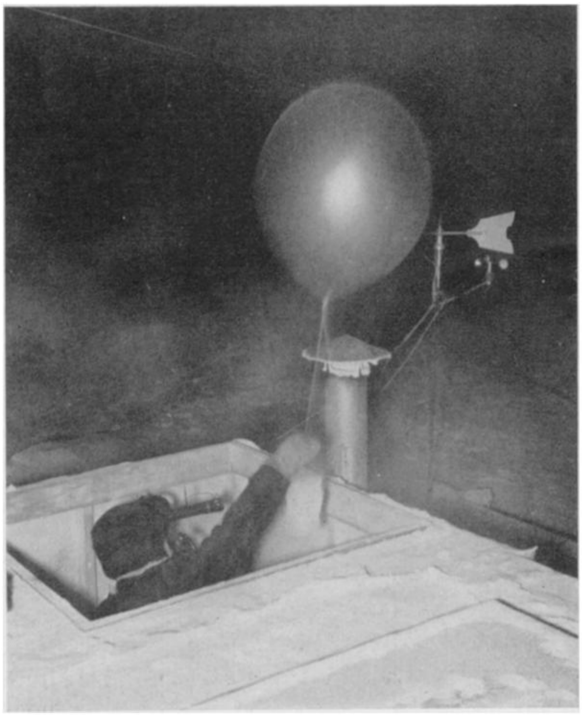

FIG. 9. Night-time balloon run. A 30-gram balloon with paper lantern attached being released through observatory hatch. (Official U. S. A. S. photo.)

release seemed to prolong the runs somewhat, although it is believed that the ordinary candles furnished simply will not burn at temperatures lower than −50° C. (−58° F.).

One major difficulty with night-time observations, which has already been mentioned, was reduced visibility caused by clouds of vapor rising from the heated buildings. The only solution to this problem would have been the removal of the observation point some distance from the buildings—a project not carried out because of lack of materials for a new shelter and scarcity of wire for extending the telephone system, to say nothing of lack of time for the observer, who was then chiefly preoccupied in efforts to obtain higher radiosonde observations.

As a consequence of these difficulties, the night-time runs were, on the whole, disappointing, the longest being 21 minutes but most ending at 5 or 6 minutes. With the sun's return on August 22, however, daylight runs with 100-gram balloons again became possible and were made diligently, so that a relatively large number of observations were obtained from then until the end of the program three days before the ships' sailing.

In September clear skies for days at a time permitted exceptionally long runs. To increase the accuracy of observations in the bitter cold of −50° C. to −60° C. (ascents were followed consistently to bursting at 40 to 50 minutes), two men alternated at 10-minute intervals at the theodolite, while a third recorded inside the building. This eliminated the danger of hasty readings resulting from necessarily frequent pauses to rub the face to prevent frostbite, if a single observer were to remain at the eyepiece for the entire hour required.

Since one of the research problems upon which data were desired from this expedition was that of vertical wind structure in inversions, readings were made in almost all ascents at half-minute intervals for the first 10 minutes, the routine 1-minute intervals being used thereafter. In some cases, when it appeared that the balloon would soon enter a cloud layer, half-minute readings were continued after 10 minutes had elapsed.

In calculating the results, the ascension rates adopted in 1939 by the Weather Bureau were employed, direct interpolations of altitude being used for the half minutes. For the 30-gram balloons, distance tables were available, but none had been as yet published for the 100-gram balloon, so that comparison of the distances obtained by slide-rule computation with the recently published tables shows some discrepancies. These are, so far as has been found, less than the margin of error in plotting and thus do not affect the accuracy of the results.

This use of the standard Weather Bureau pilot balloon altitudes (and distances) probably introduces a constant source of error in the results, since these tables are based upon double theodolite observations made generally on warm days. Obviously, the 10 per cent increase in ascension rate during the first 5 minutes of the run, generally attributed to local turbulence or possibly convection, should not be used for ascents made over a perfectly level snow surface, especially in a pronounced inversion with consequent complete lack of convection.

It had been hoped originally that double theodolite observations could be made *in situ* to obtain more accurate altitude values, but, owing to the scope of the meteorological program and the lack of any trained assistants for the observer, this was impossible. However, double theodolite observations may be made later under somewhat similar surface conditions—such as might be found over the northern Plains States in the wintertime—and from their results the West Base observations may be recomputed on a more accurate basis.

In both the 30-gram and 100-gram ascents, directions and velocities were obtained over 2-minute periods, except that during the first 10 minutes values were obtained for 1-minute intervals, using alternate readings. To obtain this increased detail, the plotting board was modified by the addition of a distance scale twice that of the ordinary one.

Of the 233 numbered ascensions, 14 did not attain the minimum elevation of 1,000 feet (330 meters) required by Weather Bureau regulations and therefore should not have been counted. Most such runs were made to determine ceiling heights, since no ceiling balloons were available.

All observations up to August 6 were completely plotted, graphed, and summarized in the field, as were all observations from August 17 to September 10 and a few other observations made in September and December. With the aid of Messrs. Anderson, Hafer, and List, of the Weather Bureau Central Office, the work was completed in 1941.

Except when upper air data were urgently needed for flight operations, all computations and plotting of pilot balloon ascents were left to the assistant, and this work of Harrison H. Richardson and Malcolm C. Douglass was of great help to the meteorological program. Both became competent observers as well as recorders and computers.

Owing to the liberal supply of 100-gram balloons provided, many high ascents were obtained. The pure-gum balloons often were followed to bursting point, and several times, notably during the extremely cold September days already mentioned, they were observed to burst into 2 halves which kept their shape several minutes before disintegrating. This behavior was distinctly attributable to extreme cold, since companion radiosonde observations showed temperatures colder than −80° C. (−115° F.) at the common bursting level of 14 kilometers, which is considerably lower than the normal bursting point for 100-gram balloons.

On the few occasions when red 100-gram balloons were followed to bursting (in general, red balloons were used only against high altocumulus or cirroform clouds and thus were usually lost before bursting), the bursts came at lower levels than those of pure-gum balloons, indicating that dye decreases the elasticity of rubber at low temperatures.

The 30-gram balloons provided had even less elasticity than the 100-gram balloons, being completely inelastic at observed surface temperatures of −50° C. (−58° F.). These balloons were furnished only in red and in black, and black seemed to have slightly better elastic qualities at low temperatures. The lack of pure-gum latex 30-gram balloons was keenly felt, since their availability probably would have extended nighttime runs several minutes.

Although the number of ascents (219) is considerably less than that of either of the two Byrd expeditions, the use of 100-gram balloons, not generally available for those expeditions, renders the current set of observations fully as valuable as any previous upper air data for the Antarctic. If there had been no radiosonde program to occupy most of the time of the single observer, or if two or more professional meteorologists had been assigned, even better results would have been obtained.

RADIOSONDE OBSERVATIONS

From April 26, 1940, until January 15, 1941, a period of almost 8 months, 190 radiosonde ascents were made at West Base. Of this number, 188 attained the minimum height of 3 kilometers now required by the Weather Bureau, and only 8 failed to reach 6 kilometers. This upper atmosphere sounding program, the most comprehensive ever made on the Antarctic Continent, revealed the startling disappearance of the stratosphere during the Antarctic winter and its unexpected warmness during the summer.[7]

The Weather Bureau purchased from Julien P. Friez and Sons, of Baltimore, 200 RaySondes of the Diamond-Hinman pattern. The Friez Company generously lent the complete ground equipment necessary, including duplicate units to insure continuity of operation. No late-model equipment was available except for a Cyclo-Ray recorder.

The Weather Bureau provided 223 of the standard Darex 350-gram balloons purchased from the Dewey and Almy Chemical Company, of Cambridge, Mass. Owing to the extreme unlikelihood that any instruments after use would survive blizzards long enough to be recovered by the few field parties contemplated, no parachutes

[7] Tropopause Disappearance During the Antarctic Winter. *Bull. Amer. Meteor. Soc.*, **23**; 220–238, 1942.

were provided. Nor were drag balloons provided, since sluggishness of humidity elements is the chief reason for requiring moderate ascension rates in low levels under temperate conditions, and temperatures encountered were always below 0° C., where hair hygrographs are unreliable. This did not impair the altitude computations, since the virtual temperature correction at 0° C. is less than one-half a degree.

In all, 134 cylinders of hydrogen were furnished for the combined radiosonde observation and pilot balloon ascent programs. Hydrogen was chosen in preference to heilum, because its greater compressibility and lifting power rendered necessary the transportation of fewer of the cumbersome 135-pound cylinders—a vitally important consideration in a 12,000-mile shipment by truck, steamer, and dog sled.

On the whole, radiosonde observations were made daily, an effort being made at all times to space the observations equally over the available time.

After the inauguration of the program it was found that release of the balloon and instrument was well-nigh impossible in winds of more than 17 or 18 miles per hour. Thus, since operations of other camp equipment on the common electrical system (specifically, the many schedules of the radio department) left only a few hours during the day available for ascents, many days were skipped on account of high winds. When observations were not precluded by other causes, they were sometimes purposely skipped to avoid exhausting the supply of instruments before the end of the program.

Several attempts were made to launch balloons during winds exceeding 18 miles per hour, but they always ended unsuccessfully and often with damage to the instrument. Because of the general flatness of the surrounding terrain, the vertical gradient of wind velocity is exceptionally steep, so that even an over-inflated balloon, when released in a strong wind, will not rise at all but will be forced down against the surface by the faster-moving air immediately above.

A serious factor which regularly limited the height of wintertime ascents is the general inability of pure-gum latex rubber to retain elasticity at temperatures below −80° C. after previous chilling. Thus, while ascents at tropical stations have registered temperatures as low as −90° C., the balloon there is exposed to these temperatures for a relatively short time—usually less than half an hour—whereas in Antarctic wintertime operation the entire ascent is made at temperatures far below 0° C. and the balloon is thoroughly chilled long before reaching this critical level of −80° C. Despite low temperatures, however, there were no cases of failure which seemed attributable to freezing of batteries or to the effects of cold upon the transmitter.

Batteries provided were of three types: 100 standard dry batteries, some $3\frac{1}{2}$ by 3 by 2 inches, weight about 350 grams, with expected shelf life of 90 days; 120 large size dry batteries, twice the weight of the standard ones and correspondingly larger, with an expected shelf life of 6 to 9 months; and 50 wet batteries, containing a 3-cell A section and 60-cell B section, weighing about 200 grams. Since ascents did not begin until 9 months after packing of equipment, considerable deterioration of the dry batteries was anticipated.

These small batteries performed well, although more than a score were rejected because of dead cells and other failures. Their average life in the air was about $1\frac{1}{2}$ hours, and thus it was fortunate that they were used at a season when extremely low temperatures aloft limited ascents to 15 kilometers or less. The larger dry batteries proved excellent, and more than 15 months after their manufacture they gave runs of 3 and 4 hours with no noticeable loss of strength.

Wet batteries were used only as a last resort. Aside from an annoying tendency of both terminal leads to break off, these proved hard to charge and had a life of barely 1 hour—a most annoying curtailment when ascents had been averaging 3 hours.

Serious difficulties arose from the irregular power supply and from interference, not only from the base radio transmitter but from other electrical equipment. Utilization of a motor generator would have insured a constant power supply, and advance arrangements should have been made to guarantee quiet periods, thus eliminating much of the interference. In an effort to maintain constant communication with the outside world, radio schedules were maintained throughout the day and night. These schedules were frequently changed, forcing the observer to operate at unpredictable odd hours in hope of obtaining an undisturbed signal.

In addition, measurements of radio signal strength of two United States stations were made every 6 hours, demanding shutdown of all electrical apparatus during the 5 minutes necessary for the observations.

The radio department, with its two 500-watt and one 100-watt transmitters located only 25 feet from the RaySonde receiver and with attennae strewn in every direction from the building, was the chief source of interference, but other equipment, such as battery charger, washing machine, and razors, contributed its share.

Since the assistance given to the meteorological department was on a voluntary basis, there were a few times when radiosonde observations were skipped to avoid inconveniencing an assistant. In all, more than half of the camp personnel of 33 men aided in launching balloons at one time or another during the program.

From October 13 to November 9 observations were very infrequent because of the stripping of four teeth on a recorder gear. Eventually a replacement was sawed and filed out of bakelite. During the 28 days of recorder shut-down, seven ascents were made and data were obtained by reading visually the frequency meter dial and noting the exact times of contact switching on a sweeping second-hand watch, and by drawing the values on recorder paper for evaluation.

Chief of the inherent difficulties encountered in the equipment used was in obtaining a steady record at extremely low audio frequencies corresponding to low temperatures. Lack of standard gas-filled coaxial cable and dipole antenna was keenly felt, since home-made dipoles of ordinary insulated copper wire with twisted pair lead-in gave far less signal strength than could have been obtained with the standard system.

Ground checking of instruments before flight was a continual source of trouble. As a result, the accuracy of the temperature values on many of the ascents is open to some question. In brief, the problem was to cool the instrument to outside temperature as quickly as possible so that the pre-heated battery would not be too greatly chilled before release.

All preparations for release of RaySondes were made in the large inflation room already described (in the discussion of pilot balloon ascents —see preceding section). The standard practice was to take the RaySonde, with heated battery freshly installed, outside into the inflation room. There it was placed upon the test switch, brought out at the same time, and connected to it. A standard Fahrenheit thermometer was so suspended from a string that its bulb was inside the thermoshield, often touching the temperature tube. Either a standard psychrometer or a standard minimum thermometer was used, depending on whether the temperature was above or below the freezing point of mercury.

After 5 to 10 minutes had been allowed for cooling, the observer reentered the cold inflation room, read the suspended thermometer, connected the two wires of the RaySonde, and hurried back to the building. All practicable precautions were taken to insure escape of a minimum of warm air from the building to the adjacent inflation room, and the observer tried to keep heating from his person as low as possible.

Back inside the building the observer tuned in the RaySonde. As soon as 3 sets of contacts had been obtained, he again went out, read the suspended thermometer and disconnected the instrument. Good agreement was obtained between the two contacts and their corresponding temperatures, but because the air surrounding the instrument was cooling during the check period, the second reading almost always was lower than the first, and thus few records show two check contacts agreeing with each other.

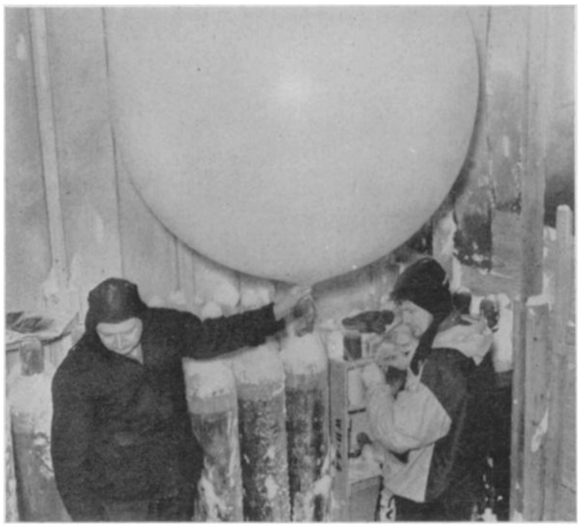

FIG. 10. After the ground check of RaySonde, observer and assistant (H. H. Richardson) go to inflation room, clip wires off instrument, and prepare it for flight. (Official U. S. A. S. photo.)

The check completed, the observer and his assistant worked as rapidly as possible to put the apparatus into the air before too much additional cooling took place (fig. 10). The balloon, whose inflation had been completed about the time that the instrument first was taken outside to cool, was tied and the instrument was secured to the cord. The assistant climbed the ladder to the roof and caught the neck of the balloon as it was slowly let up from below. While the assistant paid out the cord, the observer went to the roof, pulled up the instrument by the string, and gave it a last-minute check before passing it to the assistant for releasing.

Release was made from one of the corners of the roof of the inflation house (fig. 11) as soon as the observer, who had descended to the receiver, called out that the signal was being received satisfactorily. Until actual release the instrument was usually held firmly against the roof so that it was not exposed to true air temperature until the assistant began to permit its ascent (fig. 12). Final setting of the baroswitch was made on the floor of the inflation room at outside temperature just before the instrument was pulled up to the roof for release. This setting of the switch at temperatures quite different from those at which the original calibrations had been made, introduced a serious error increasing with altitude.

This error is due to temperature effect on pressure element and is inherent in the metallic nature of the aneroid element. It can be eliminated from radiosondes either by elaborate automatic compensation, similar to the temperature compensation used in good, well-built aneroid barometers, or by applying corrections based on tests of the individual instrument. If the instruments are sufficiently standard, the error can be eliminated by application of mean corrections. Mean corrections have been determined by the Friez Company and are given graphically in the latest (1941) edition of their "Instructions for Installation, Operations, and Maintenance" of the equipment.

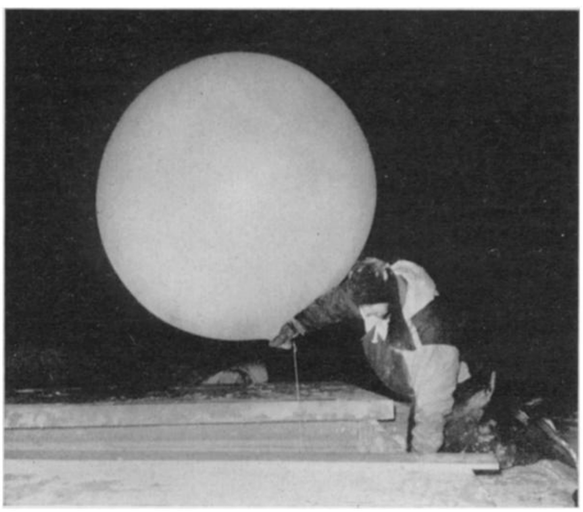

FIG. 11. Observer lets balloon up gently to assistant. (Official U. S. A. S. photo.)

FIG. 12. Final check of instrument before balloon is released. (Official U. S. A. S. photo.)

In order to eliminate this and possibly other errors made in the original work while in the field, the entire series of radiosonde observations is being recomputed.

RESEARCH PROBLEMS

The specialized meteorological research program planned for West Base was for the most part abandoned, owing in large measure to lack of wire for instruments and also to lack of time on the part of the observer. On the problem of vertical wind and thermal gradients only the former was measured; several attempts to obtain data on the temperature distribution near the surface met with no success.

Inasmuch as neither conventional sunshine recorder nor rain gauge would operate under expected conditions, neither of these instruments was used. Instead, the second pen of the triple register was connected to a standard anemometer located 1 or 2 meters above the snow. While not quite so easy to read as the regular anemometer pen trace, this record is readily interpretable to give the wind velocity at the lower level and thus, by comparison with the standard trace, an indication of the gradient.

Three standard 3-cup anemometers were rotated between the two positions, so that any instrumental error could be deducted and compensated.

To measure the temperature gradient three telethermoscope bulbs were provided. One was

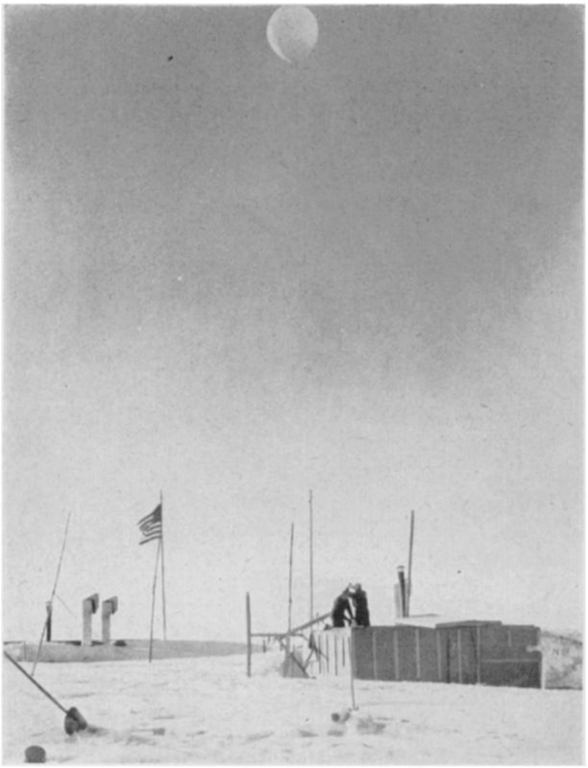

FIG. 13. Radiosonde release in summer. (Official U. S. A. S. photo.)

mounted in normal manner in the thermometer shelter. A second was placed in an especially constructed louvred box, 18 inches on each side, mounted on the anemometer pole opposite and below the upper anemometer. As far as possible, this box was oriented for least interference with air flow to the anemometer, and its effect upon the wind record is believed to have been negligible. The third bulb, of the flat, bladelike type, was placed 1 centimeter below the surface of the snow. Wires from all three were run alongside of the wind-recording cable to the weather office, where a knife plug and three ordinary house lighting sockets were used as a switching device between the elements and the telethermoscope itself.

Late in August, after three months of unsuccessful endeavor, owing, in the main, to lack of wire necessary for properly wiring the circuits, a final effort to measure the temperature gradient was made. A new telethermoscope bulb, with 50 meters of rubber-covered, 3-conductor cable attached, was borrowed from Dr. Wade. Two 8-foot lengths of ¾-inch pipe were joined together and mounted upright in the snow as far toward the thermometer shelter as the cable would allow. The bulb was suspended from a short cross-arm attached to the top of this pipe some 5 meters above the snow. By means of a stout string threaded through a loop at the end of this cross-arm and run through a hole in the snow to one of the sub-surface tunnels of the camp, it was possible to raise and lower the thermal element. The inner end of the string was measured off in ½-meter lengths and so calibrated that, although beyond view, an assistant could tell exactly at what elevation above the surface the bulb was suspended. The weight of the electric cable kept the suspending string nearly vertical. By these precautions all effects of the observer on the temperature to be measured were eliminated. The pole was to the southwest of the camp buildings, and most of the gradient measurements were taken either during periods of southwest airs, characteristic of settled conditions with lowest temperatures and most marked inversions, or during southeast blizzards, with high surface temperatures due to large-scale mixing of the warm inversion air with the cold surface air.

Observations were made in daylight and in darkness, on clear days and on cloudy, and with wind velocities varying from calm to 12 m. p. s. (25 m. p. h.). The rate at which the element was raised and lowered was varied from 1 minute to 15 minutes for the 5 meters. Nevertheless, no consistent difference was found between any 2 points between the surface and 5 meters.

FIG. 14. Recording a radiosonde ascent. H. H. Richardson is plotting a pilot balloon ascent, while the observer is receiving and computing the radiosonde data. (Official U. S. A. S. photo.)

Either the method employed was not sufficiently accurate or there was no appreciable thermal structure to the surface air, although during the time of observation surface temperatures varied from −55° C. (−70° F.), with a pronounced inversion at 1 km., to −22° C. (0° F.), with no inversion.

Shortage of wire likewise handicapped the radiation-measuring program; consequently less than two score determinations were obtained.

During the course of observations certain limitations developed in the use of the melikeron approximate black-body pyranometer (fig. 15).[8]

FIG. 15. Melikeron (approximately black-body) pyranometer in position for radiation measurements. (Official U. S. A. S. photo.)

First, the instrument must be kept at a fairly uniform temperature. Under conditions as encountered, this meant, in effect, that observations could be made only when the instrument was to windward of the camp. Since wiring prevented ready moving of the melikeron, it could be used only when air motion was from it toward camp buildings. Second, radiation to and from a homogeneous sky only could be measured. Scattered or broken clouds caused wide fluctuations in radiation, and thus readings were possible with clear or over-cast skies only.

Observations were begun by Dr. Wade early in May 1940 after he volunteered to take charge of the program. First exposure of the instrument was through an escape hatch from the balloon inflation shed directly above a door of the heated science building. After some two weeks, observations were discontinued pending relocation of the instrument at a place free from local heating effects. Press of other work interfered, and a month elapsed before additional wire was found and the instrument was relocated some 50 feet from the building. In bringing the instrument into the building to remove drift snow from the honeycomb, Dr. Wade tripped, and, in falling, broke the legs of the instrument loose.

Two more months elapsed before the instrument was repaired, and another before it was warm enough outside to dig up the wire and relocate it. Observations finally were begun on October 6 and were continued as opportunity offered until January 16, when the instrument was dismounted and packed.

A total of 28 determinations were made in this period. The number of observations was limited not only by the need for homogeneous sky, as discussed above, but also by the length of time needed for one observation, usually an hour or more.

Two other research problems in meteorology were initiated by Paul Siple, the base leader, and were carried out with the use of Weather Bureau equipment furnished and maintained by the observer.

One was an attempt to determine the amount of cold air drainage into the shallow valley (Eleanor Bolling Valley) just northwest of camp. For this project 10 minimum thermometers were so mounted on exposed boards that they could

FIG. 16. One of a series of minimum thermometers being read by I. N. Schlossbach and Loran Wells on their daily round. Ten thermometers were mounted identically on exposed boards to obtain a thermal cross-section of Eleanor Bolling Valley. (Official U. S. A. S. photo.)

[8] A honey-comb radiator-absorber, in which the amount of electric heating necessary to maintain equilibrium indicates radiation amount. Instrument developed and made by Smithsonian Institution.

be turned upward for resetting (fig. 16). They were placed on the rim of the valley, half-way down the slopes, and in the center. During the dark months they were read daily, except when blizzards prevented, by two camp members (Isaac Schlossbach and Loran Wells), and the uncorrected readings were entered in a special book.[9] Recalibration upon their return to Washington of all the surviving minimum thermometers, including about half of those used in this study, revealed the unreliability of such instruments at low temperatures, so that the accuracy of their readings is no better than a whole degree.

Demanding greater attention was the second problem, an effort to determine the relation of rate of cooling to temperature and wind velocity. Although this problem has been studied extensively in laboratories under controlled conditions, Dr. Siple designed his own experiments for field conditions. The results of this study[10] will be used to determine the weather's danger point to man in terms of wind velocity and temperature.

FIELD OBSERVATIONS

The first weather observations to be made outside the camp limits were those of a three-man party which went out 14 miles in mid-winter darkness to photograph aurora simultaneously with photographs made at the base. Two separate trips were made one month apart. Aside from noting sky and weather conditions, and the temperature (which reached −70° F.) as indicated by a minimum thermometer, no weather data were accumulated.

In mid-September an advance party of four men set out by tractor to haul a preliminary load of fuel and to mark the eastern trail toward the nearest mountains. Only fragmentary temperature and weather entries were made on this 16-day trip.

In mid-October the three major field parties, totaling 11 men with 7 dog teams, left. After helping establish the Seismic Station in the Rockefeller Mountains, these parties pushed on eastward. Each party carried one or more aneroid barometers, one maximum and two minimum thermometers, and one special "trail-type" thermometer box already described.

[9] "Micro-climatological Tables with Foreword": appendix 2, West Base Narrative, Official History and Record, U. S. Antarctic Service (unpublished).

[10] *Cf.* Siple and Passel, *Proc. Amer. Philos. Soc.* **89**: 177–199, 1945.

In general, entries in the specially designed meteorological trail logs were made twice daily, at the start and end of each day's run. A few entries were made at other times, principally in the hope of establishing heights of various points. These observations have been used to determine approximate heights of all camp sites, as fully discussed in a separate report.

Most important of the field weather observations were those made irregularly from November 1 to December 29 at the Seismic Station on Mount Franklin in the Rockefeller Mountains of King Edward VII Land. In all, 117 observations were made, all at one of the four Greenwich times also used for observations at the main base some 120 miles away, and by trail parties in the vicinity. The number of observations made at each time was:

GMT	0000	0600	1200	1800	Total
November	25	24	10	4	63
December	17	18	11	8	54
Total	42	42	21	10	117

The observations were made by Roy G. Fitzsimmons, physicist of the expedition, who had had considerable previous meteorological experience. The equipment included an aneroid barometer, a small 3-cup airway anemometer connected to a blinker light, a microbarograph, and a trail-type thermometer shelter for maximum and minimum thermometers. A mercurial (Tuch) barometer and shielded board were transported laboriously to the site, only to be found unserviceable because of a loose cistern screw, so that all readings were made with an aneroid barometer. The maximum thermometer was broken after a week's use; thus no mean temperatures are available.

The tent and equipment at the Seismic Station were situated on a level stretch of ice about 100 feet square which lay in a corner formed by the eastern side of the mountain and a level ridge of rock trending eastward from the northeast corner of the mountain.

Barometric computations give the camp altitude as 1,280 feet, within 10 feet; position, latitude 78° 06′ S., longitude 155° 30′ W.

CONCLUSION

Considerable space has been devoted in this report to describing and explaining the difficulties of meteorological observation under Antarctic conditions. Recommended precautions for future expeditions are:

1. *Personnel:* Each major base of operations should have at least two qualified observers whose primary intention and responsibility it is to obtain as many observations as possible.

2. *Quarters:* Adequate housing must be provided for all observational equipment, on a site carefully selected for optimum exposure as well as convenience in wiring and working, and preferably in a separate small building well removed from sources of electric disturbance (for radiosonde work) and of smoke and vapor (for pilot balloons and visual observations).

3. *Program:* Not only must a complete program of work, with numerous alternatives, be prepared in advance, but it must be accepted by all those in authority, so that weather observations will not be sacrificed to other duties.

4. *Equipment:* All instruments must be carefully selected in anticipation of the particularly rigorous use anticipated, and the climatic conditions to be experienced. In particular, they must be adjusted to the expected temperature range, or even designed and constructed especially to minimize the effects of contraction (in clocks, anemometers and other moving instruments), of loss of elasticity (balloons) or combustibility (candles) or conductivity (batteries), and to withstand fine driven snow (thermographs). Obviously, they must be calibrated in advance for the conditions they are expected to measure.