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International Geophysical Year

A Report on the United States Program

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The International Geophysical Year began on 1 July and will continue through all of 1958. This article presents a brief account of some of the activities during the first five months, 1 July to 30 November 1957.

Although this account is primarily concerned with the United States program, some references are made to the activities of other participating countries. It should be noted that 67 countries are cooperating in this study of the earth and its cosmic environs; the types of work described here are also being conducted by other national IGY groups. For convenience the IGY investigations may be classified under three categories: (i) the physics of the upper atmosphere, (ii) the earth's heat and water regimen, and (iii) the earth's structure and interior. Subjects in the first category include solar activity, aurora and airglow, cosmic rays, ionospheric physics, and geomagnetism. This category also includes rockets and satellites, tools for sending instruments into the upper atmosphere. Subjects in the second category include meteorology, oceanography, and glaciology, and those in the third include seismology, gravity, and determinations of longitude and latitude.

The following sections report briefly the activities in each of the fields in each of the three categories. A final section outlines aspects of the collection and interchange of data in the IGY program.

Physics of the Upper Atmosphere

Solar Activity. As particles radiated from the major solar flare of 28 June 1957 began to arrive at the earth, two days later, a storm wracked the earth's magnetic field. The ionosphere—the layer of electrically-charged gas between about 40 and 200 miles above the earth's surface—was torn by electrical disturbances; long-range radio communication was blacked out for a long period of time. The flare was first observed at the Krasnaya Pakhra Observatory in the Soviet Union. Immediately a message was flashed to the World Warning Agency operated for the IGY by the National Bureau of Standards at Fort Belvoir, which declared a state of "alert," beginning at 1600 Universal Time, 28 June. Alerts are declared when there is probability of solar disturbances. When the possibility is high that terrestrial disturbances will also occur, Special World Intervals are promulgated, calling for an increased number of measurements of solar-terrestrial phenomena. The first such interval in the IGY was declared 29 June, to commence at 0001 Universal Time on 30 June. Throughout the world observations of the sun were intensified, and balloons and instrumented rockets were sent up by many nations to observe the increased ultraviolet and x-radiation and to monitor cosmic ray intensity. Observations and measurements were speeded up to record more carefully and fully the northern and southern lights, to measure disturbances in the earth's magnetic field, and to probe the ionosphere.

During periods of maximum solar activity radio communications are often interrupted by "fadeouts" or "blackout," particularly after the occurrence of a flare on the sun. On these occasions pulses transmitted to the ionosphere by ionospheric sounders are not reflected as usual but are absorbed. It had long been thought, but not heretofore conclusively established, that this absorption must be caused by increased ionization in the lower atmosphere. On 4 July, radio signals received from a rocket fired up through the ionosphere demonstrated the presence of an additional layer of ionization extending for about 12 miles below the normal lowest point. Even more remarkably, the rocket data showed that the normal ion distribution throughout the ionosphere above the D, or lowest, layer, seemed to remain undisturbed during the blackout. In another recent IGY rocket experiment, it was ascertained that the additional electron layer was caused by solar x-ray emission associated with the occurrence of solar flares.

Rockets are only one means of studying solar phenomena. Solar astronomers have organized themselves in a worldwide solar patrol, keeping watch on the sun all over the world throughout the 24 hours of the day. Solar observation stations are operated by 33 countries; of 126 stations all over the world, 14 are operated by the United States, not including rocket-firing sites.

By observing the sun through special filters which limit transmission to the light of certain radiations of hydrogen or calcium, astronomers look for the giant eruptions or flares on the sun which are responsible for radio blackouts, auroras, and magnetic storms. Very narrow band filters are used, since the flares would otherwise be invisible against the bright surface of the sun.

Special instruments are also in use to photograph the chromosphere of the sun, a shell of very incandescent gas just above the sun's surface, and the corona, an envelope of gas that may extend all the way to the earth. The chromosphere and corona are invisible except when an eclipse shuts off the light of the disc, or when the sun is artificially eclipsed in a special telescope called the coronagraph. Using the coronagraph, scientists are able also to photograph solar flares at the edge of the sun; these flares sometimes shoot out into space for

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several hundred thousand miles at very high speeds.

At Mount Wilson Observatory in California, measurements are being made of the magnetic field of the sun at its surface. It has already been found that magnetic fields at the sun's surface may be very high, as much as 8000 times that of the earth's field at the equator. These magnetic fields are thought to play a very important role in disturbances and storms on the sun's surface as well as in sunspots.

Geomagnetism. Thirty countries throughout the world are operating 129 magnetic observatories, from the North to the South Pole and in almost every region of the earth's surface; 31 of these stations are part of the United States program in geomagnetism.

Newly established United States IGY geomagnetic stations are in operation in the Arctic, in the Pacific Ocean, in continental United States, and in South America with the cooperation of IGY scientists in Peru. Certain of these stations are set up in chains, with carefully planned spacing, to study in detail the magnetic storms which occur during great solar disturbances. It has been suggested, but not before positively established, that the magnetic effects we observe on earth during magnetic storms may be due to great electric currents, of perhaps several hundred thousand amperes, flowing around the earth high in the atmosphere. Two of these currents are believed to circle the North and South magnetic poles, while the third circles the earth at the geomagnetic equator. This theory is being examined.

The stations in South America and in the Pacific Ocean—at Guam and Koror in the Western Pacific and at Jarvis, Palmyra, and Fanning islands in the Eastern Pacific—were established especially to study the existence of the so-called "electro-jet." The electro-jet is believed to be the equatorial electric current, but narrowed down into a "neck" of limited horizontal dimensions with consequent increased current density and intensified activity at local noon. The U.S. Coast and Geodetic Survey, which operates many of the magnetic observatories established by the United States, reports tentative confirmation of this phenomenon. Initial data from Koror reveal the existence of the equatorial electro-jet and its rather limited horizontal extent.

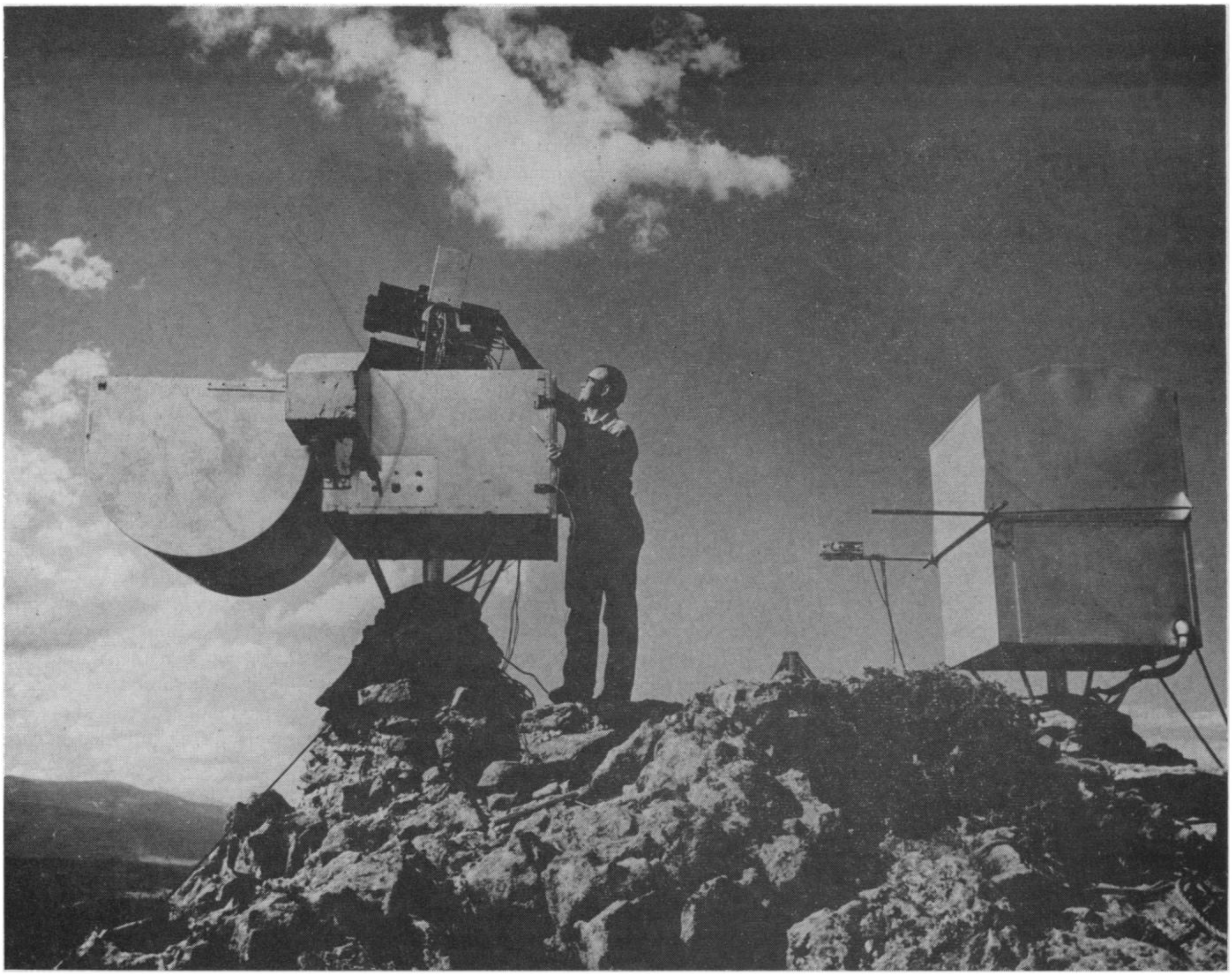
Parabolic antenna, with aurora borealis in the sky, used at College, Alaska, to study radio noise and radio wave reflections from the aurora. [Stanford Research Institute]

Aurora and airglow. A world-wide comprehensive auroral observation program in 49 countries is under way for the first time during the IGY. Many of these 49 countries are in low latitudes where auroras are seldom seen. Nevertheless, in all of them, auroral reporters have been appointed to collect reports of visual observations in the event that a very great aurora should occur. A number of such auroras have been reported in the last century, but these events of great scientific importance have usually been inadequately described. One hundred and forty-two camera and instrumental auroral observation stations, as well as extensive amateur visual observing programs, have been organized in 17 countries.

The 39 stations and hundreds of amateurs participating in the United States program have already had much to observe. The fact that the IGY was scheduled for a period of expected maximum solar activity has greatly enhanced the value of the program, for already three of the largest solar flares (class 3+) have resulted in extensive auroral displays visible as far south as Havana, Cuba. Synoptic maps have been prepared depicting all auroras observed and reported from the United States during the months of July and August. This is the first time that such a complete description of auroral data has been assembled for the use of geophysicists studying auroral and such related phenomena as ionospheric and geomagnetic effects.

English scientists at the University of Manchester have reported that simultaneous radar observations indicate that auroras occur simultaneously in the Northern and Southern Hemispheres, a condition long believed to be true by scientists, but not previously established. Additional polar radio data which provide further evidence on this question have been obtained in the United States program.

The systematic reduction of the variations in the intensity of the night air-



First IGY scanning photoelectric photometer, situated on top of Fritz Peak, near Boulder, Colorado. This instrument selects and measures the intensity of light too faint for the human eye to detect and records its changes, converting the light into electric signals. [National Bureau of Standards, Boulder Laboratories]

glow is proceeding. Charts of the "patchiness" and movement of night sky luminosity resulting from oxygen emissions are being produced on a routine basis from IGY observations.

Ionospheric Physics. One of the major problems in ionospheric physics is predicting the future state of the ionosphere. If we can determine the condition of the ionosphere in advance, we can do much to develop more reliable radio communications, with direct rewards in safer travel in the air and at sea. Forty-one nations are conducting studies of the ionosphere during the IGY, and a world-wide network of 253 ionospheric observing stations has been established. Seventy-one of these stations are sponsored by the United States. The data obtained by the network will provide a world-wide picture of the behavior of the ionosphere.

New information about the farthest reaches of the atmosphere is being obtained from the study of "whistlers"—whistlelike sounds which can be detected at very low radio frequencies. These signals, originating in lightning flashes at the surface of the earth, swing out thousands of miles along the earth's lines of magnetic force before they return to the opposite polar hemisphere. Early IGY experiments demonstrated that the ion density and molecular concentration along the whistler path at altitudes of as much as twice the earth's radius must be much greater than formerly anticipated. Indeed, there seems to be confirmation for the theory that the earth's atmosphere extends far beyond the level where it had been previously thought to "end" and that there may be a very tenuous atmosphere—the sun's corona—filling all the space between the earth and the sun.

Other records of previously unexplained radio noise at very low frequencies have stimulated the hypothesis that solar particles arriving in the very high atmosphere transfer energy to very low frequency radio waves there. According to this hypothesis, the radio signals thus amplified are the very low frequency radio emissions observed at ground level. Data now being gathered will throw further light on this hypothesis, which is based on the traveling wave tube principle noted by Roger Gallet.

Ionospheric characteristics are deduced from the analysis of echoes arising from the reflection of radio pulses transmitted to the ionosphere at vertical incidence. Since the IGY began there have been several major solar events that caused disruption of long-range, short-wave radio communications which depend upon reflections from the ionosphere. For the first time, a synoptic picture has been obtained of the growth and decay, station by station, of such fade-outs.

The principal regular variation in the

ionosphere is the diurnal one. Ionization density increases during the day when the sun is present and decreases at night. What would happen to the ionosphere during long absences of solar radiation and the nature of any diurnal variation that might occur during such periods have been subjects of speculation. Only at or near the geographical poles can these questions be examined, and the South Pole affords the best platform for an observatory. Investigations during the last year at the United States' South Pole Station have yielded interesting results: in spite of the absence of the sun, the electron concentration seems to remain very high throughout the polar night; moreover, there is a diurnal variation that can only, it appears, be associated with geomagnetic activity. The evidence so far obtained suggests that ionospheric behavior in the two polar regions is essentially the same. Analysis of these observations may appreciably alter our concepts of the ionization and recombination processes in the atmosphere.

Cosmic Rays. Cosmic rays are electrically charged particles which bombard the earth continuously and from every direction. Although their existence has been known for fifty years, their source and precise nature remain uncertain. In particular, the source of these particles is one of the major questions in astrophysics, and the answer is one of major importance in understanding the cosmos from which the rays take their name. These particles, consisting largely of nuclei and having energies ranging from 10^8 to 10^{19} electron volts, are influenced by the earth's magnetic field. Low-energy particles are deflected toward the vicinity of the two geomagnetic poles, and only the more energetic ones penetrate at the middle latitudes.

During the IGY, the scientists of 31 nations are studying cosmic rays at 195 stations; neutron monitors and meson telescopes, cloud and ionization chambers, special photographic emulsions, and window Geiger counters are being used. Rockets and balloons, as well as earth satellites, are important tools for observing these rays. Typical of international cooperation during the IGY is the Swedish-Canadian-American cosmic ray experiment carried out aboard the Swedish merchant ship *M/S Lommaren,* sailing between Sweden and the Union of South Africa.

Investigations at the 20 United States cosmic ray stations have already provided interesting results. The work of scientists from the University of Chicago has shown that the location of the line where the cosmic ray intensity is at a minimum—the "cosmic ray equator"—deviates systematically from the geomagnetic equator. The experiments leading to this result began in 1954–55 when a neutron pile detector was installed aboard the *U.S.S. Atka,* which conducted a reconnaissance of the Antarctic prior to the establishment of IGY stations in following years. Measurements were made on the trip down to and around Antarctica and back; these measurements were repeated aboard the *U.S.S. Arneb* during the 1955–56 and 1956–57 seasons in Antarctica and were supplemented by aircraft flights in a zigzag pattern around the geographical equator, in October 1956. These studies showed a 40- to 45-degree westward shift of the inclined cosmic ray equator with respect to the magnetic equator. J. A. Simpson suggests that this warping may well indicate the presence of important magnetic fields, probably of extraterrestrial origin, which alter the trajectories of the incoming primary cosmic ray particles.

Preliminary balloon flights in and near Minnesota with balloons that carry ionization chambers have shown that, at constant altitude, there is a strong latitude effect. This effect is so strong that changes in latitude of as little as 7 miles can be detected by cosmic ray measurements. Other balloon experiments, at Fort Churchill and Thule, have shown that cosmic rays of lower energy (less than about 2 Bev) have essentially disappeared during the present period of high solar activity, with ionization at high altitudes down to half the value it had in 1954 or 1955.

Perhaps one of the most interesting observations made in the course of IGY cosmic ray experiments was that of relatively soft radiation in the high atmosphere, associated with primary auroral radiations. Rocket and balloon flights have led to the positive identification of the soft radiation: it is x-radiation in the range between 10^4 and 10^5 electron volts. There appears to be good correlation between the presence of such radiation and solar, magnetic, and auroral activity. The effect is probably a secondary one; it is believed that incoming auroral particles create the x-rays by bombardment of atmospheric particles.

Rockets and satellites. Rockets provide one of the two important ways of directly measuring phenomena and processes in the upper atmosphere. Rockets are, moreover, unique in that they permit studies of the altitude-dependence of various quantities and events—for example, temperature, pressure, density, and composition. Seven nations are engaged in rocket programs: Australia, Canada, France, Great Britain, Japan, the United States, and the U.S.S.R.

Some 200 rockets are involved in the United States rocket effort. Firings are under way in the Arctic, Antarctic, Pacific, and continental areas. A major facility at Fort Churchill, Manitoba,

Circular plots of the 5577-angstrom airglow intensity in the entire sky, as observed at intervals throughout the night of 1–2 October 1956 at Fritz Peak, Colorado. The outer edge of each circle corresponds to a distance along the earth's surface of about 470 kilometers from the observer, who is in the center of the circle. In preparing these isophote maps, the general increase of intensity toward the horizon has been eliminated. [Courtesy Franklin E. Roach, National Bureau of Standards, Boulder Laboratories] within the north auroral zone, was constructed in cooperation with Canada, and a joint Canadian-United States program is under way.

There were 29 rockets fired in the pre-IGY test period. These included Aerobees, Rockoons and Nike-Cajuns. Firings took place at the newly erected facilities at Fort Churchill as well as at White Sands (New Mexico) and Guam, and from shipboard off the California coast and in the North Atlantic. These firings were successful, and the preliminary information gained was of considerable value in the final detailed planning of the schedules for firings during the IGY period.

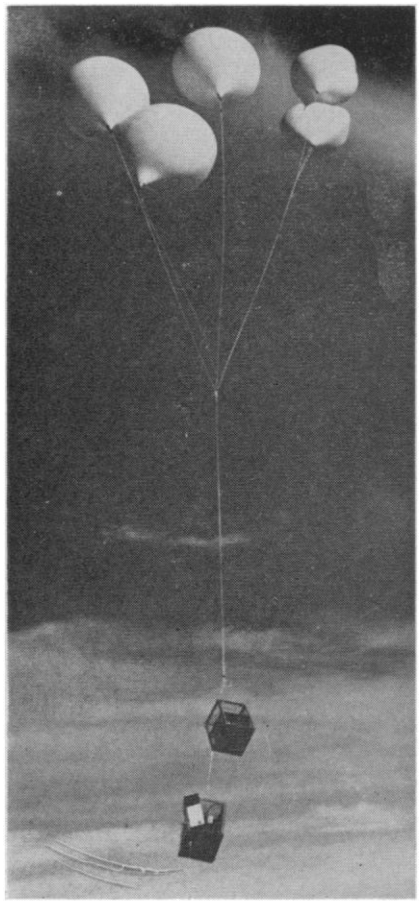
The United States IGY program in rocketry actually began on 5 July 1956 at Wallop's Island, Virginia, when the first IGY test rocket was fired successfully. To date, 81 rockets have been fired during the IGY. Included have been those in programs conducted at Fort Churchill (nine Aerobees, five Nike-Cajuns); White Sands (two Nike-Cajuns); Point Mugu, San Nicolas Island, California (13 Nike-Deacons); a shipborne operation in the Arctic (18 Rockoons); and a shipborne operation in Pacific and Antarctic waters which was concluded in mid-November (36 Rockoons). The following are some preliminary findings:

1) A firing at Fort Churchill indicated that the first atmospheric temperature maximum occurred at an altitude of about 60 kilometers. Normally this maximum is found below 50 kilometers at lower latitudes, indicating that, at northern latitudes, the rise is more gradual. (Temperatures decrease up to the stratosphere, rise during the next 20 to 30 kilometers, decrease through the next 30 kilometers, and then rise again.)

2) A rocket, instrumented for ionospheric studies, was sent through a polar blackout for the first time. Data were obtained which indicated that a very dense D-region exists at a significantly lower altitude, and with a much greater density, than is found at lower latitudes.

3) A firing at Fort Churchill during the summer of 1957 measured electron distribution in the ionosphere up to an altitude of 250 kilometers during a polar blackout. The results of this experiment confirmed theories that the D-region of the ionosphere is primarily responsible for radio blackouts.

4) During a series of firings with Aerobees and Nike-Cajuns instrumented for studies of pressure, temperature, and density, it was determined that the distribution of pressure and temperature in the atmosphere at high latitudes is very different from what it is at lower latitudes. Many of these rockets attained altitudes greater than 200 kilometers, and thus the first density measurements made at high latitudes were recorded. Launchings were made during both summer and winter, day and night. The resulting data indicate that the density of the high atmosphere is under strong solar control. There appear to be a latitude effect, a seasonal effect, and a strong diurnal effect; none of these effects appear at lower altitudes at Fort Churchill or lower latitudes.



A group of small weather balloons used to test a timing device prior to the use of similar devices on Deacon rockets to measure cosmic radiation and the temperature, density, and pressure of the upper atmosphere. [U.S. Navy]

5) An experiment with a mass spectrometer at Fort Churchill appears to confirm the belief that diffusive separation of gases under gravity is present above 100 kilometers at that latitude. Below this point the gases in the atmosphere appear to be well mixed.

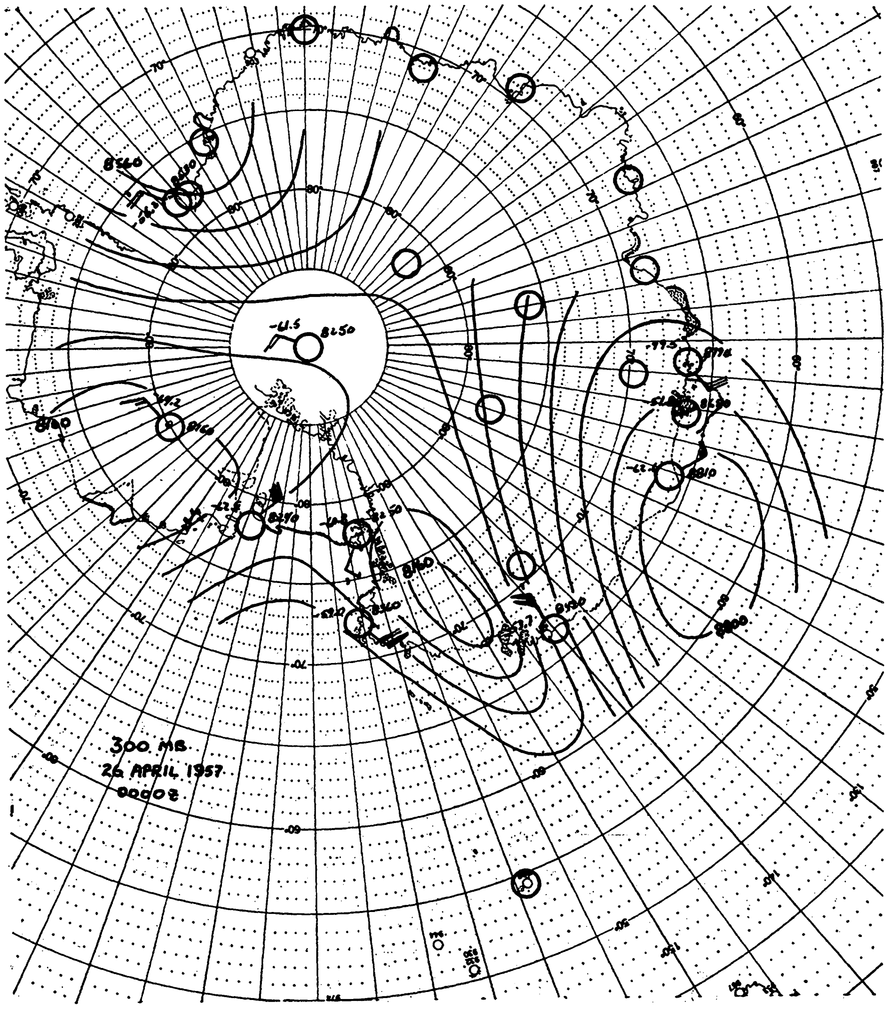
6) During July and August 1957, the DAN rocket flare patrol program took place at Point Mugu, California. This program was primarily directed toward determining the radiation source of the fadeouts resulting from flares observed on the disc of the sun. For the first time, measurements were made of x-ray and ultraviolet bursts from the sun during a solar flare. These data will help in explaining radio blackouts, which are present during periods of unusually high degree of ionization, and which are closely associated with solar flares.

7) During the shipboard firings in the Arctic, an excellent survey was made for the first time of auroral particles and their association with actual aurorae. Also conducted for the first time at high latitudes were magnetic field measurements.

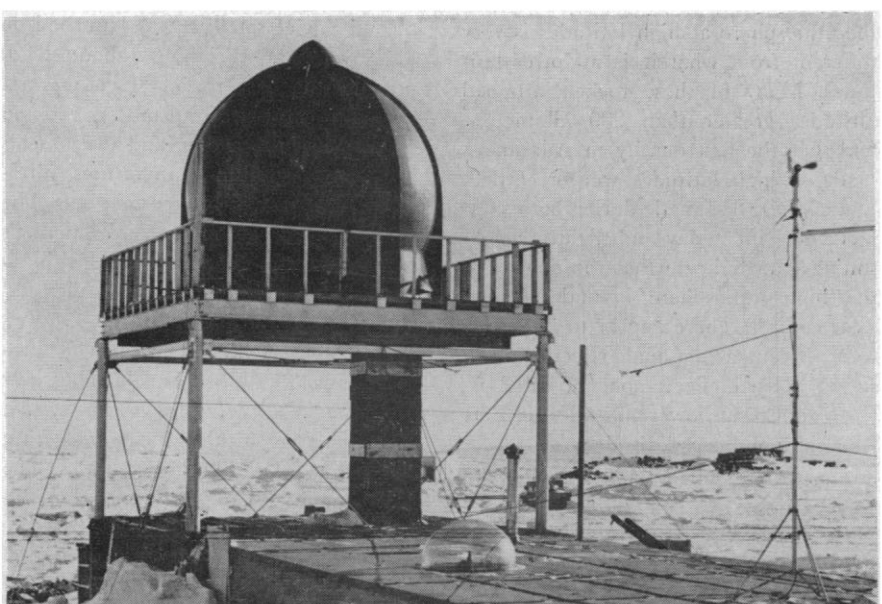
Satellites represent an extension of rocketry useful in probing the high atmosphere. Satellites provide means to secure data on the variation of phenomena with time and over a vast expanse of space. Two nations are engaged in satellite-launching programs: the U.S.S.R. and the United States. Many nations are cooperating in tracking and ground-based observations. In the United States program, precision radio and optical stations have been established not only in the United States but in 13 other countries whose scientists are cooperating closely with the United States scientists.

The U.S.S.R. launched its first satellite on 4 October 1957. This satellite, a sphere nearly 23 inches in diameter and weighing about 184 pounds, carried transmitters broadcasting on frequencies of 20 and 40 megacycles per second. The second Soviet satellite was launched on 3 November. Weighing about 1120 pounds, the last rocket stage was reported to carry two transmitters (20 and 40 megacycles), a dog, and instruments to measure satellite temperatures, ultraviolet light, x-rays, and cosmic rays. The initial period of the second satellite's revolution was 103.7 minutes, with an apogee of approximately 1056 miles and perigee of about 150 miles.

The United States program is proceeding according to schedule. The Navy has responsibility for the rocket system and launching in the Vanguard series; the Army, for the Jupiter-C series. The IGY Committee of the National Academy of Sciences is responsible for the scientific aspects for both the internal experiments and the radio and optical observation programs. Two types of satellites have been designed: test spheres for use during the test period for the Vanguard rocket system and equipment-laden satellites for use there-



Atmospheric circulation at the 300-millibar level at 0000 Greenwich Mean Time, 26 April 1957, based on Weather Central data. Heights are given in meters above sea level; temperatures are in degrees centigrade; arrows show the direction of the wind; wind speed is indicated by one full barb for each 10 knots and by a filled-in flag for 50 knots. [U.S. Weather Bureau]



The Rawin tower at the Little America IGY Station housing radar equipment for tracking meteorological balloons. [U.S. Navy]

after for both the Vanguard and Jupiter-C vehicles.

The test spheres are 6.4 inches in diameter and weigh 4 pounds. They have six 12-inch antennae and six solar cells mounted on the skin. These spheres are designed primarily to transmit signals for radio tracking purposes; they carry two separate transmitter systems operating on frequencies of approximately 108 megacycles. One is battery-powered, while the other is powered by the six solar cells, affording the prospect of indefinite transmitter life.

The IGY equipment-laden satellites have three main configurations. All but two are 20-inch spheres constructed primarily of magnesium, weighing 21.5 pounds, and equipped with four 29-inch antennae. Of the other satellites, one is a sphere approximately 13 inches in diameter, with a protruding cylinder approximately 13 inches long and 2.5 inches in diameter; this satellite will be accompanied by an inflatable sphere, 30 inches in diameter and weighing less than 0.7 of a pound, which will be ejected from the carrier rocket at the same time as the satellite is released. The last configuration, a cylinder to be launched in the Army vehicle (Jupiter-C), is of approximately the same weight as the spherical satellites to be launched in the Navy Vanguard rocket.

Equipment carried by these satellites will include instruments to measure the intensity of the solar hydrogen Lyman alpha line; temperatures of the satellite's surface and interior; meteoric erosion, flux, and penetration; geographical, temporal, and altitudinal variations of primary cosmic ray intensity; total magnetic field at altitudes above the more densely ionized regions of the upper atmosphere; air drag; the geographical distribution of the energy received by and radiated from the earth; and the changing patterns of the cloud cover of the earth.

The satellites will be located and data will be obtained from them by means of radio, precision camera, and visual observations. The precision radio tracking system is known as Minitrack; it was developed by and is operated under the supervision of the Naval Research Laboratory. There are ten Minitrack stations, most of them along the 75th meridian West.

The 12 precision optical tracking stations, using Baker-Nunn Schmidt-type cameras, are under the supervision of the Smithsonian Astrophysical Observatory. They are located in one longitudinal and two latitudinal belts (75th meridian West and 30° to 40° North and South).

There are three programs based on amateur participation in satellite tracking which are designed to supplement precision tracking efforts. The first, for volunteer visual observation teams, is being administered by the Smithsonian Astrophysical Observatory and has been named Moonwatch. Over one hundred Moonwatch teams, located both in the United States and abroad, have been registered and are in operation.

A similar program, called Moonbeam, has also been established to coordinate the participation of radio amateurs and other volunteer groups having the capability to record telemetry and radio position data. Employing Minitrack II, developed by the Naval Research Laboratory, and Microlock, developed by the Jet Propulsion Laboratory of California Institute of Technology, these volunteer groups supplement the primary Minitrack stations in tracking the satellite and should also provide valuable scientific data.

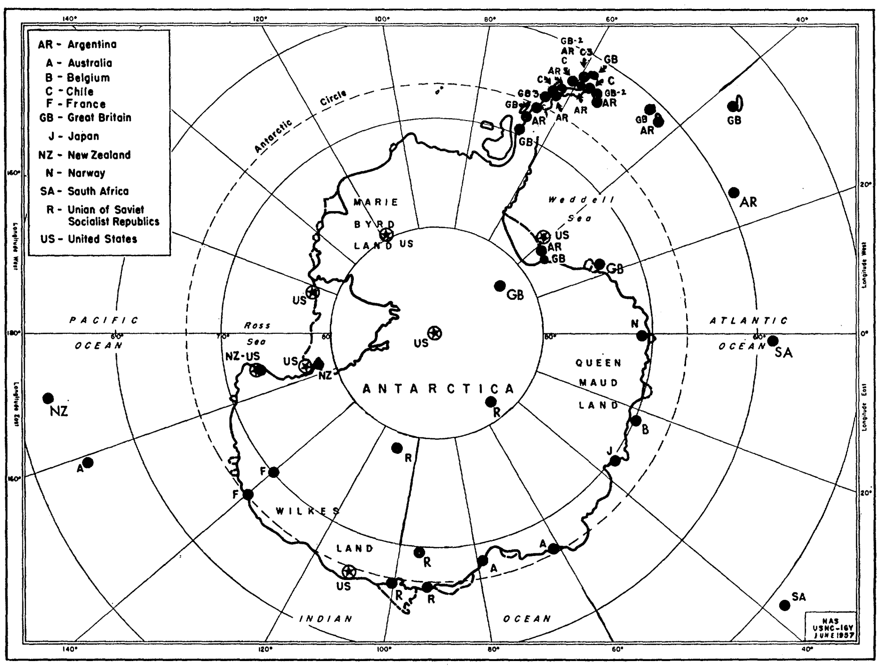
The third volunteer tracking program is called Phototrack; it was organized under the supervision of the Society of Photographic Scientists and Engineers. Participants in this program use standard cameras of good quality to photograph the satellite against a fixed background of stars of known positions.

Earth's Heat and Water Regimen

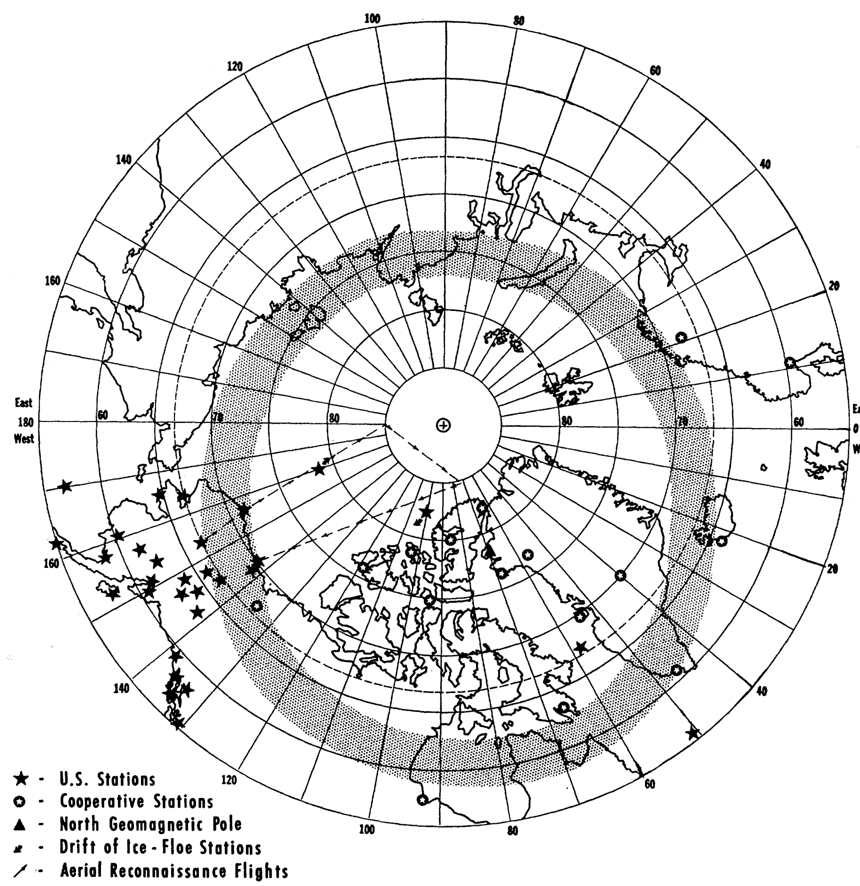
Meteorology. Almost all of the energy that the earth receives comes from the sun. This energy evaporates water from the oceans, lakes, and rivers; heats the ground, which in turn heats the air above it; and in general supplies all the energy which drives the winds of the atmosphere.

In the equatorial regions there is more energy received from the sun than is lost back to space; in the polar regions the reverse is true. Since we know that, on the average, considering a year's time, the earth as a whole does not heat up or cool off appreciably, the excess energy gained in the tropics must be balanced by the loss of energy in the polar regions. The flow of energy between the tropics and the poles is part of the driving force of the atmospheric circulation. A very important factor in the general circulation also is the rotation of the earth. As is well known, the speed at the surface, due to the daily rotation of the earth, is greatest at the equator, which is farthest away from the axis of rotation, and least in the polar regions, becoming zero at the pole itself.

In order to study the winds and circulation of the atmosphere during the IGY, meteorologists of nearly every participating country have intensified their efforts at setting up new stations in hitherto uncovered areas and are making every attempt to send meteorological balloons as high into the atmosphere as possible to measure temperature, humidity, and winds; all countries are collecting meteorological data. In cooperation with the Canadian Weather Bureau, the



IGY stations in Antarctica for the International Geophysical Year. [National Academy of Sciences]



Features of the IGY program in the Arctic region. [National Academy of Sciences]

U.S. Weather Bureau is operating some key stations in the Far North, supplementing its complex of stations in Alaska and the United States. In cooperation with scientists and weather bureaus of the various South American countries, five new complete weather observatories are now in operation in Chile, Peru, and Ecuador. These five stations are important in a chain of stations reaching from the North Pole, where the U.S.S.R. maintains a station, through Canada, eastern United States, the Caribbean Sea, western South America through Antarctica, and finally to the South Pole, where United States scientists have established a complete scientific observatory.

In addition to this chain of stations, 12 nations have cooperated in locating more than 50 scientific observatories in the vast unknown continent of Antarctica. For the first time, synoptic meteorological charts of this area are being drawn on a daily basis. Weather forecasting has already been markedly improved in the Southern Hemisphere. Aside from the forecasting and synoptic aspect, the scientific value of the observations in Antarctica are potentially of great value in understanding the atmospheric circulation and its relation to solar radiation and topography.

The Antarctic is the coldest place on earth. The continent itself is elevated and mountainous, the South Pole being almost 10,000 feet above sea level. Byrd Station, in the interior, has reported temperatures of about 100 degrees below zero (Fahrenheit), and recently the South Pole Station reported an even lower temperature, 102.1 degrees below zero.

In the Antarctic meteorology program, large neoprene balloons have been sent to altitudes of over 80,000 feet, and the average is about 60,000 feet. Meteorological balloons sent up at 112 non-Antarctic United States stations are reaching altitudes ranging from 85,000 to 107,000 feet, carrying instruments to radio back to the ground the temperature and humidity.

In addition to these broad-scale programs, several specialized programs are under way, and preliminary results have been received. For example, there is in Little America an instrument which measures the minute quantity of ozone in the air at the ground level. Ozone mainly occurs in a layerlike region about 15 miles high in the earth's atmosphere. Some ozone diffuses to the ground or is formed at lower levels by ultraviolet light. It has been noticed that, at Little America, there is about 25 percent more ozone at the ground than there is in New Mexico. Although ozone is a minor constituent of the atmosphere, it is thought to play an important role in the circulation of the high atmosphere, because of the energy it can absorb and release.

Another minor constituent of the atmosphere which may play a major role in climatic changes is carbon dioxide. This compound is present in the atmosphere in amounts of about 350 parts per

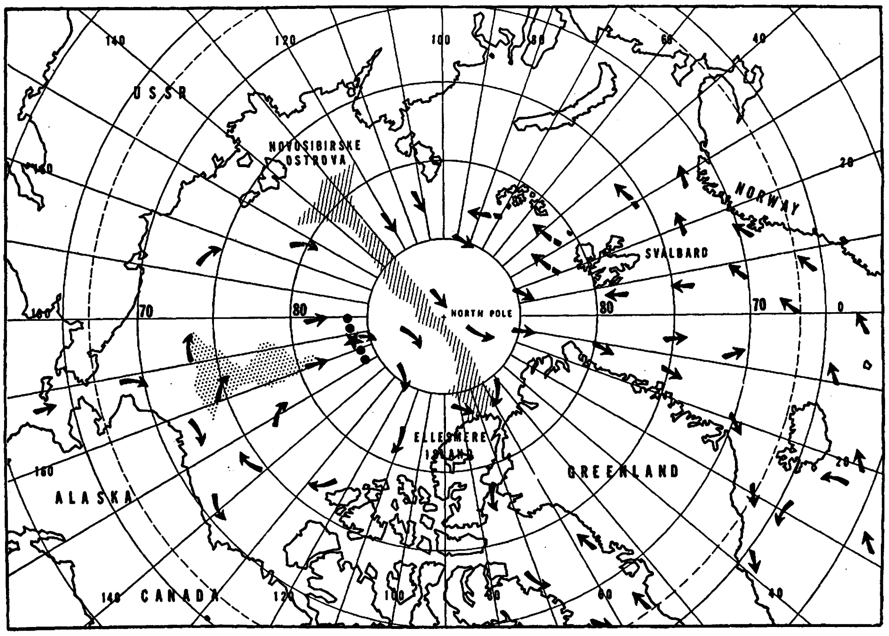


Chart of the Arctic basin. The black star marks IGY Drifting Station A, at the approximate position of the newly discovered submarine ridge (black dots). The vertical pattern shows Lomonosov submarine ridge; the stipple pattern shows the Chukchi submarine peninsula. The solid arrows represent major known surface currents; the broken arrows represent major known subsurface currents. [National Academy of Sciences]

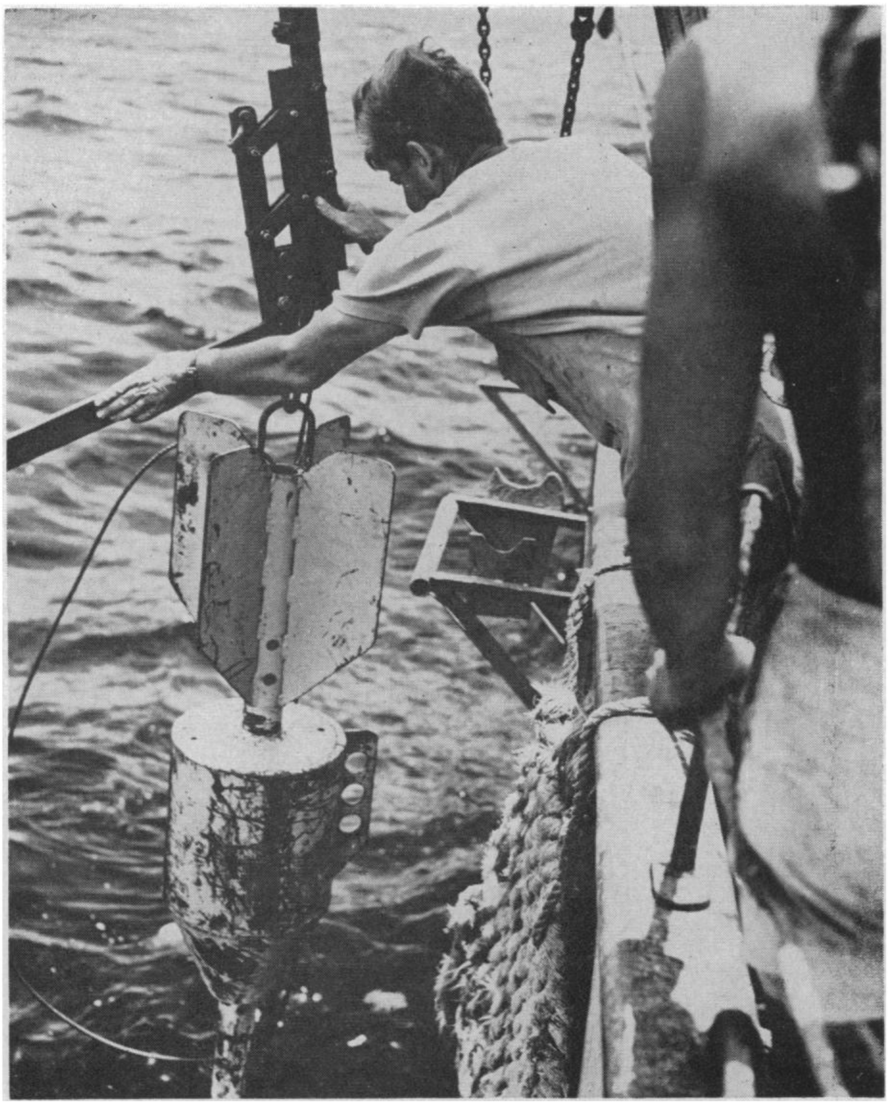
U.S. Weather Bureau scientists at IGY Drifting Station A, coring with a hand auger to drain off the "melt water"—ice which has melted on the surface. During summer months this melting ice makes construction and camp maintenance difficult. [U.S. Weather Bureau] million. It absorbs infrared or heat radiation and may act like a trap for such radiation, much as glass does in a greenhouse, and it may play a very important role in the heat balance of the atmosphere. Our industrial civilization burns tremendous quantities of fossil fuel each year, pouring millions of tons of carbon dioxide into the atmosphere. Most of this is absorbed by plant life and by the waters of the oceans, but there is the possibility that eventually the carbon dioxide content of the atmosphere will rise enough to affect the world's climate. At United States stations and aboard ships, there are seven instruments in use monitoring the content of carbon dioxide in the atmosphere, and scientists are collecting thousands of air samples for later analysis. It has been found already that the concentration of carbon dioxide in the Antarctic is about what it is over the rest of the world away from immediate industrial contamination.

The United States National Committee for the International Geophysical Year was designated by the Comité Spécial de l'Année Géophysique to establish and maintain a Weather Central at the Little America Station to collect and disseminate Southern Hemisphere weather information, particularly for the Antarctic region. The basic program at Weather Central involves the reception and recording of weather data from many contributing sources; preparation and analysis of meteorological charts, maps, graphs, and cross sections—mostly synoptic; and broadcasting of current weather information and analyses for use in forecasting by stations throughout Antarctica and the remainder of the Southern Hemisphere.

The Weather Central staff consists of United States meteorologists together with meteorologists assigned, in turn, by other nations participating in the Antarctic program.

Preliminary reports indicate that significant improvements in the weather forecasts of Southern Hemisphere countries have been made since data from the Antarctic Weather Central became available.

Glaciology. United States glaciologists are encamped on glaciers and ice fields in Greenland, on the frozen Arctic Ocean, in the mountains of Alaska, on a small glacier in the state of Washington, and on the ice shelves and the great ice sheet of Antarctica, in a broad program designed to map not only the extent of the glaciers and ice but also to understand their flow and their relation to and effect on the local climate. Twenty-seven other



Oceanographers lowering coring apparatus from the side of the *Vema,* an oceanographic research vessel operated by the Lamont Geological Observatory. The coring device is designed to take samples of the bottom sediment. It is a metal tube, 30 to 60 feet long and about 2 inches in diameter, which is lowered vertically, with a heavy weight on the top. When it is about one hundred feet from the bottom, a small trigger weight releases the weighted pipe, which then sinks into the bottom. The core is then withdrawn and hoisted to the ship. [Lamont Geological Observatory]

countries are also making observations covering all the known ice areas of the world, including glaciers on the equator —at Mount Kilimanjaro and Mount Kenya in eastern Africa.

Technical advances and discoveries have already been made in the two greatest reservoirs of ice in the world, Greenland and Antarctica. In Greenland, scientists of the U.S. Army's Snow Ice and Permafrost Research Establishment have perfected techniques for drilling deep holes in the ice with hollow drills, much as an oil well is drilled, to obtain a "core" of ice. The first hole was drilled in Greenland in 1956 and reached a depth of over 1000 feet. The second hole was successfully drilled in 1957 in Greenland, and a similar operation is now under way in the Antarctic in Marie Byrd Land.

The recent boring in the ice of Greenland reached a depth of 1438 feet. A complete series of cores 4 inches in diameter were obtained from the first 1040 feet. Below this depth, recovery of the core is difficult because the release of strains as the ice is drilled causes the ice to shatter. Dissolved gas, which is under great pressure in the ice at these depths, also causes trouble because it bursts through pockets in the ice, increasing the amount of shattering. However, a core was obtained from 1200 to 1220 feet, and another from 1320 to 1338 feet. These cores are being studied with great care in the laboratory, for they are an invaluable index of climate and precipi-

Rev. Daniel Linehan, using the 45-channel seismic recorder at Cape Roydes, McMurdo Sound, Antarctica. [D. Linehan, S. J. Weston Observatory]

tation over the past many hundreds of years. Their layers are studied in much the same fashion as tree rings are studied. From the first hole in Greenland, the 1912 layer was identified by the ash from a volcano which erupted in Alaska. The dust from the great explosion in 1883 of the volcano Krakatoa, in the East Indies, will be a help in checking the dating of the annual layers of precipitation in the cores. Because precipitation is lower in the Antarctic than in Greenland, it is expected that this ash layer will be found at a depth of about 150 feet in Greenland and at about 60 feet in the Antarctic.

The great ice sheet of the Antarctic, over 6 million square miles in extent, cannot be studied in anything but a spotty fashion. However, teams of glaciologists, seismologists, and support personnel are traveling by tractors and special over-snow vehicles thousands of miles across the ice in a series of traverses to obtain the profile of ice thickness across the continent and to attempt to learn something of the underlying terrain, or formation of the ice-covered earth. For example, after the Byrd Station was established some 600 miles from Little America by a tractor party, a traverse team then crossed the ice shelf from Little America and continued to Byrd Station, exploring the ice as it went.

The surface ice is examined by taking samples and determining the density, digging shallow pits to learn about the layers of the most recent several seasons, and making measurements of the temperature and heat conductivity of the ice. The deep ice is explored by setting off small explosions on the surface and by listening to echoes reflected by the bottom of the ice and by any deeper layers of the earth's crust. The time the echoes take to return allows calculation of the depth of the ice.

During this first traverse it was discovered that Byrd Station, at an elevation of about 5000 feet above sea level, stands upon ice almost 10,000 feet thick. Further explorations will reveal whether this is a frozen fjord or inland sea and what part of this submergence may be due to the bending inward of the earth's crust as a result of the weight of the ice.

United States scientists at two locations in the Arctic basin are now making studies of the melting of the ice pack, the freezing of new ice, and the general relations between the state of the ice and the local climate. One of these stations, Drifting Station B, is on an "ice island" 7 miles by 3 miles in extent and about 140 feet thick. This block of ice was probably calved off the Ellesmere Island ice sheet many hundreds of years ago and has been circulating in the Arctic Ocean since, driven by the winds and ocean currents. This ice island, known as Fletcher's Ice Island, has been occupied previously by United States scientists in studies of the Arctic basin. It is currently at latitude 81°08'N and longitude 107°05'W, about 611.8 miles from the North Pole.

The second station, called Drifting Station A, is now located at latitude 85.30'N and longitude 170°W, 310.5 miles from the Pole. It is on the ice pack itself, on a floe a few square miles in area and only some 7 to 12 feet thick. Scientists there have noted that, during the past summer season, about 12 inches of ice on the upper surface has melted, while as much as 18 to 24 inches of new ice has frozen on the bottom of the floe. This observation will be placed in proper perspective when all the information on radiation from the sun, ocean currents, and temperatures of the air, ice, and oceans has been studied.

Oceanography. The oceans, which cover about three-quarters of the earth, are a great storage trap for energy; the oceans are responsible for the fact that the climate of lands near seacoasts is more uniform than that of the interior of continents. Great ocean currents such as the Gulf Stream affect climates in the northern parts of the Atlantic Ocean. For example, Iceland and the British Isles have far less severe winters than they would have were the Gulf Stream not flowing. The surface currents of the oceans are related to the great wind systems, and it has been shown that the Gulf Stream, for example, follows the great clockwise atmospheric circulation in the Atlantic basin. Benjamin Franklin was one of the first to observe the nature of the Gulf Stream; Lieutenant M. F. Maury, the founder of the U.S. Navy Hydrographic Office, collected much information from mariners bearing on the set and speed of surface currents in this area, and several years ago an expedition of several ships, Operation Cabot, explored the Gulf Stream in a thorough fashion. It was found that, besides the main stream, there were many small eddies and side currents.

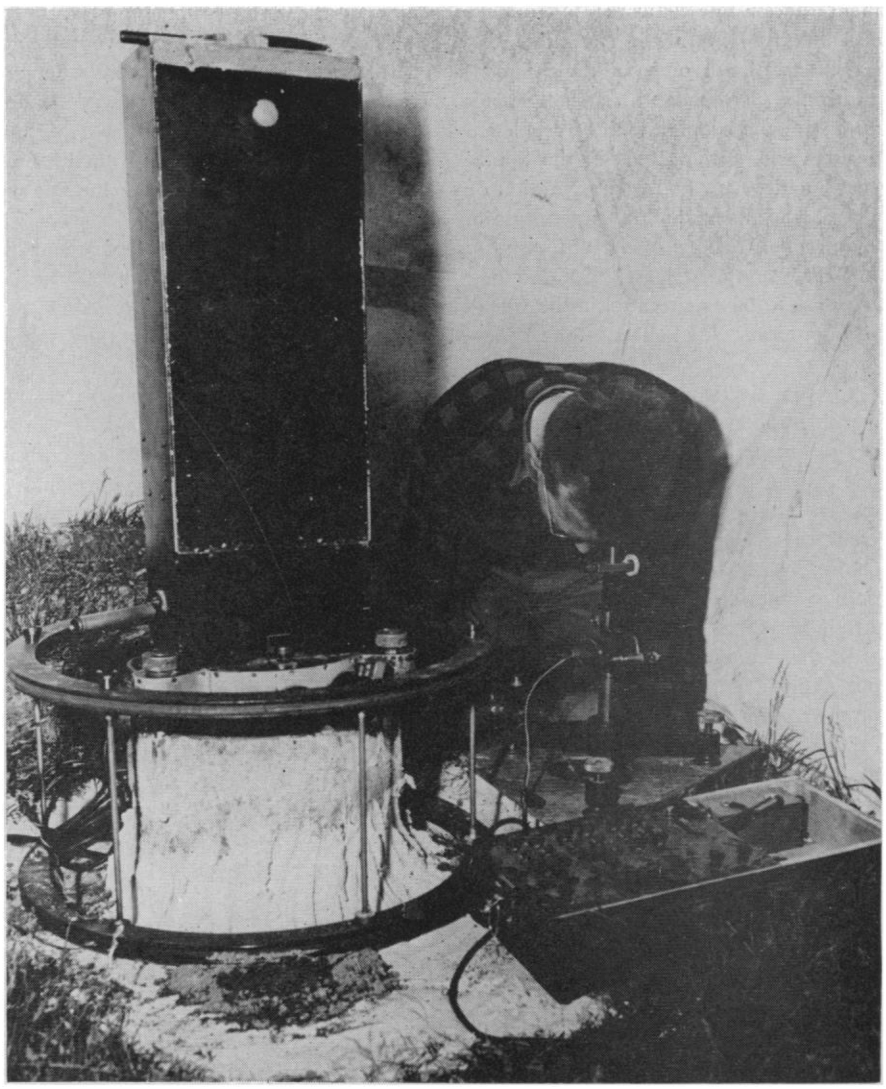
Recently, in a test of instrumentation developed by J. C. Swallow of the National Institute of Oceanography in England, the *Atlantis,* a research vessel of the Woods Hole Oceanographic Institution, and the British research vessel, *Discovery II,* explored the eastern edge of the Gulf Stream and were able to map for the first time the underlying flow of water. They found that, at depths of about 6500 feet, there was either very little or very erratic movement; shallower depths showed set to the northeast, as expected, but at depths of about 9000 feet, the current sets southwest at the relatively high speed of 8 miles per day. This new technique, in which the Swallow neutral buoyancy float is used, enables IGY oceanographers the world over to map both surface and relatively deep currents. Thirty-four countries are participating in oceanographic work for the IGY, some with ships and others with coastal and island observatories.

The deeper currents of the oceans have proved difficult to observe. Cold water is formed in the polar regions from melting ice; this water, being dense, sinks, displacing lighter water which then flows away from the polar regions towards the equatorial regions. Bottom topography such as ridges, canyons, and mountain ranges influences the flow of bottom waters, and it is possible that some bottom waters become trapped in basins. It is not known whether bottom water makes a circuit from pole to equator and back in tens, hundreds, or thousands of years. The bottom waters play an important role in man's economy, for the extent to which the seas can support life is dependent upon the food supply in the water. The bottom waters are rich in chemical nutrients, and, wherever these waters upwell, there are found the great fishing banks, such as the Grand Banks off Newfoundland and the Peruvian fishing grounds.

Several United States ships have already made extensive cruises for the IGY. The work of the *Atlantis* has already been mentioned. The *Crawford,* also of the Woods Hole Oceanographic Institution, made a four months' cruise in the Atlantic. The *Crawford* reoccupied many stations taken years ago by the German ship *Meteor* and discovered that there have been pronounced changes in the amount of oxygen dissolved in the Atlantic in the region of 15° south latitude. The difference in oxygen content over the past 30 years may mean that deep bottom water is not being formed as fast now as it was previously, but further data and analysis are needed for proper interpretation of the present observations.

The *Vema,* a research vessel operated by the Lamont Geological Observatory of Columbia University, has completed an extensive cruise in the South Atlantic Ocean, working along the coasts of South America and Africa, and crossing the Atlantic at high southern latitudes between Argentina and Capetown. The *Vema* cooperated with the *Bahia Blanca,* a survey vessel of Argentina, in making explorations of the submarine crust by seismic methods. Considerable marine biological work was also done, and Lamont has reported that living organisms—a small shellfish and a worm one-fourth of an inch long—were recovered alive from depths of 13,200 and 16,200 feet, respectively. Lamont scientists believe these to be record depths for retrievement of live marine samples. The *Vema* left New York in November for a ten-month trip to the Atlantic and Indian oceans as the second phase of Lamont's oceanographic work for the IGY.

In the Pacific, the *Brown Bear* of the University of Washington worked in the Northeast Pacific Ocean last summer. The deep currents in that area were studied. The *Horizon* and *Baird,* research vessels operated by the Scripps Institution of Oceanography of the University of California, left San Diego in October for a two-ship, five-month expedition through the Central and Southeast Pa-



Scientist reading an interferometer to measure the alignment of pendulum support in determining the value of gravity. [U.S. Coast and Geodetic Survey]

cific. They will call at Tahiti (Samoa), Easter Island, Valparaiso (Chile), and Callao (Peru) and make seismic explorations of the submarine crust, study surface and deep currents, take bottom samples, and occupy about 40 oceanographic stations, where water samples down to great depths will be obtained for later analysis of chemical content. The *Jakkula,* of the Agricultural and Mechanical College of Texas, will cruise in the Caribbean Sea and western Atlantic in the summer of 1958.

Another part of the IGY oceanography program is the study of the mean sea level over the period of the IGY. It has been found from study of tide data that there seems to be an exchange of water between the Northern and Southern Hemispheres as the seasons change. Some of the change in mean sea level between summer and winter has to do with the expansion and contraction of water with temperature. New tide gauges are being set up to supplement the existing network: instruments are already operating in Bermuda, Iceland, and the Azores, in the Atlantic, and in the Caroline and Marshall islands and, with the cooperation of French scientists, at French islands in the Southeast Pacific. A station is in operation on Pitcairn Island under the supervision of a descendant of one of the mutineers of *H.M.S. Bounty.* At least 200 tide gauge stations are being operated in the worldwide program, 32 of them by the United States.

In the Arctic basin, United States oceanographers pursue their science from camps on the frozen ocean. The track of one of the stations has carried observers over what appears to be a newly-discovered ridge, or underwater mountain chain. Scientists of the Soviet Union are doing similar work at two stations in the Arctic basin.

In the Antarctic the ships of the various nations supporting scientific stations on the continent engage in oceanographic observations en route to and from the area. Thus, U.S.S.R. and New Zealand ships have added to our knowledge of these waters. Ships of U.S. Navy Task Force 43 are also exploring the coast, charting the bottom, and taking bottom and water samples for future study.

Earth's Structure and Interior

Seismology. During the IGY, seismologists of 50 nations are obtaining earthquake information from almost all regions of the world, particularly in those regions not hitherto covered, as, for example, the Antarctic continent. In addition, several new types of seismographs with wide range and high sensitivity have been located at observatories throughout the world. The Lamont Geological Observatory has constructed ten special, long-period seismographs and has installed most of them at observatories ranging from Hawaii to Fiji and from Bermuda to the Antarctic. These long-period instruments are sensitive to surface waves with periods of about 400 seconds, generated only by the very largest earthquakes. These wavelengths are so long that they penetrate to the interior of the earth, and, in fact, the whole earth itself may be set into vibration. Recently workers at Lamont have discovered the existence of certain intermediate waves with periods of about 100 seconds. These waves, which were previously only known in the crust in continental structures, have been identified now in the mantle, or the next layer beneath the crust. These waves permit better resolution of structural details than the longer 400-second waves, and study of their propagation is expected to provide new information on the distribution of materials in the interior of the earth.

Seismologists from the Department of Terrestrial Magnetism of the Carnegie Institution of Washington worked on exploration of the roots of the Andes Mountains in South America last summer and fall. They have found roots of unsuspected depths and are now working on their data to obtain better understanding of the crustal structure under this great mountain chain.

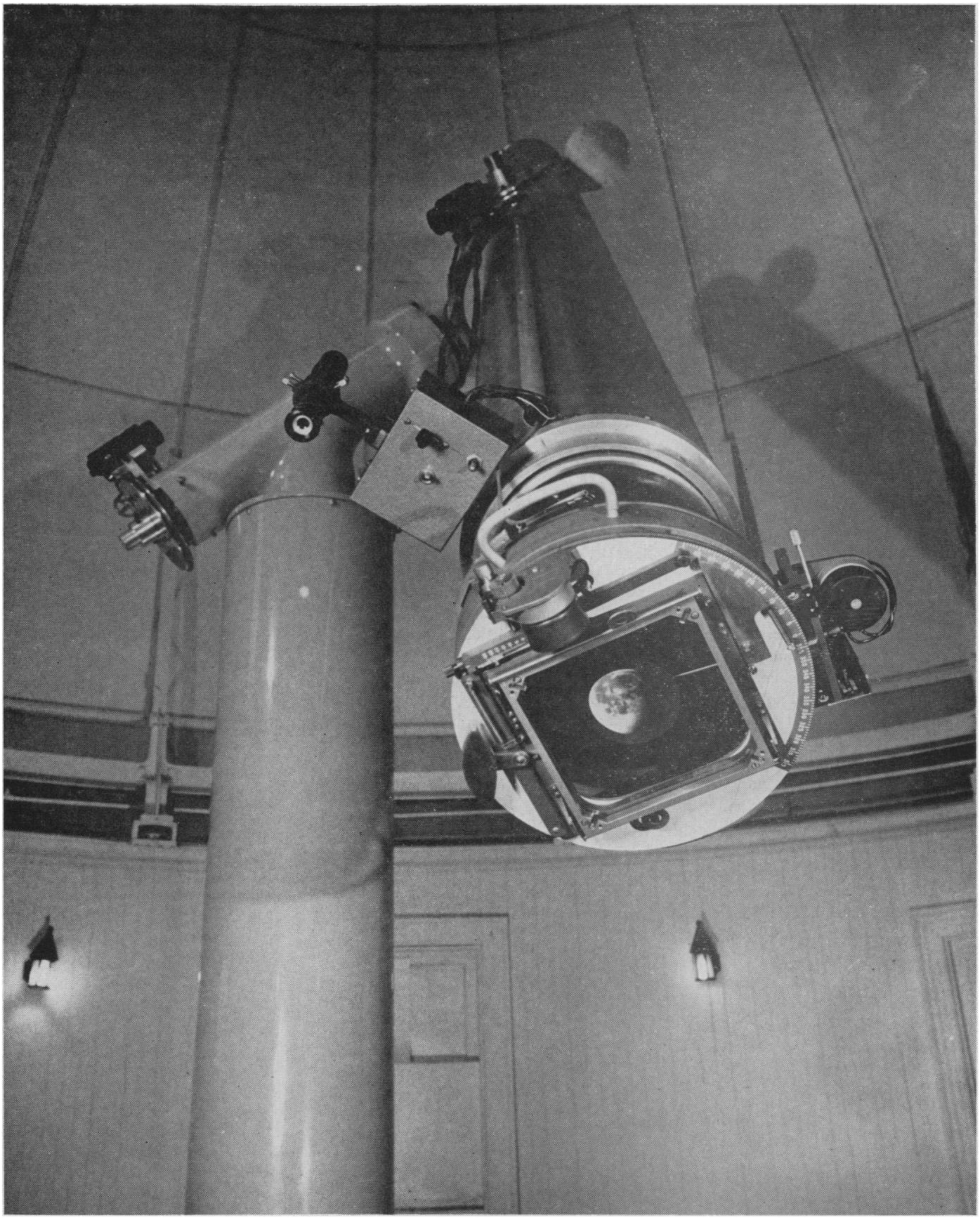
Seismologists of the U.S. Coast and Geodetic Survey have installed new seismic equipment in the Pacific at Truk and Koror and have been obtaining records of Pacific earthquakes. These new stations, together with those in the Antarctic, will add significantly to our knowledge of seismicity and the structure of the earth.

Gravity. The earth is the attracting mass for all bodies on the earth. The earth, however, is not a perfect sphere, nor is its mass uniformly distributed. Furthermore, it is rotating. These conditions add up to the fact that gravity is not uniform and constant all over the earth. In general, because of the fact that the earth bulges somewhat at the equator and centrifugal force is greatest there, gravity is least at the equator and increases toward the poles. This effect is large enough to make a 200-pound man weigh one pound more at the pole than at the equator. In addition to this nonuniformity, great continental mountain masses, underground ore bodies, undersea mountains, and, in general, the uneven distribution of mass around the crust of the earth, contribute to "local anomalies," some of which may be sufficiently large to deflect a plumb bob away from the vertical. Although this deflection is less than ten seconds of arc, there are a few locations—Puerto Rico is one—where it exceeds one minute. This effect is significant in geodesy wherever geodetic control depends on astronomical observations.

The IGY program in gravity is aimed at increasing the reliability of measurements of gravity over the world, particularly in providing very accurate and reliable measurements at certain key locations to provide connection points between the gravity networks of various countries. Many measurements have been made already, including observations in the Arctic basin taken from United States IGY stations on the drifting ice. An important new station is located in Antarctica, where first-order measurement of gravity was made to provide a calibration for future measurements in the interior.

The first successful surface measurements of gravity on the open sea were made on 22 November 1957, by J. Lamar Worzel of the Lamont Geological Observatory, who used a sea gravimeter developed by Anton Graf of Munich. In the past, gravity measurements for oceanic areas required measurements aboard submarines at quiet depths below the surface. The difficulty of obtaining and fitting submarines for this purpose made it impossible adequately to survey the seas: only about 4000 such measurements have been made throughout the world. The new instrument, mounted on a gyro-stabilized platform, will make it possible to obtain data simply and quickly anywhere at sea with a precision of one part per million, similar to that attainable on land.

As the moon rotates around the earth and the earth rotates around the sun, the solid earth undergoes the same kind of tidal bulging that occurs in the oceans, although, of course, by a much lesser amount. Yet, it is enough to be observed with the most sensitive gravimeters. As the earth heaves in tidal motion, the distance of a point on the surface from the center of the earth changes by a small amount, perhaps a few tenths of an inch



Dual-rate moon position camera and telescope. Composite photograph shows how the moon appears through the dark filter at the center. The camera photographs the moon and surrounding stars simultaneously. The position of the moon is held fixed with respect to the stars during the exposure by means of a dark filter which tilts. The photographs obtained make it possible to determine the position of the moon accurately, and from this, precise determination of latitudes and longitudes can be made, completely free of the distortion of gravity. The camera was developed by William Markowitz of the U.S. Naval Observatory. Twenty cameras have been provided to observatories scattered around the world. [National Academy of Sciences] to several inches. This can be detected directly by instruments which are now in use recording the "pulse" of the earth, instruments which are sensitive to one part in one billion of the average value of gravity.

Latitudes and longitudes. Scientists of 29 countries at 45 IGY stations around the world are in the process of determining longitudes and latitudes more precisely. Besides making transit observations at three stations, the United States is furnishing 21 of the moon position cameras developed at the Naval Observatory for use at stations in the United States and throughout the world; the first camera is now in operation at the U.S. Naval Observatory in Washington, D.C. When used in conjunction with the Danjon impersonal astrolabe, this instrument will permit more precise location of the earth's land masses than was hitherto possible.

IGY Data

The preceding sections suggest the nature of the IGY activities as shown by the United States IGY effort in the first few months of the program. With 67 nations cooperating in the endeavor and some 10,000 scientists and technicians making observations and measurements at more than 2000 stations, the volume of data stemming from the program will be considerable. To ensure the safety of the raw data and their accessibility, the international IGY committee has approved the establishment of three world data centers.

World Data Center A is located in the United States and has 11 subcenters: visual auroral observations (Cornell University); instrumental auroral observations (University of Alaska); airglow and ionospheric physics (National Bureau of Standards, Central Radio Propagation Laboratory); cosmic rays (University of Minnesota); geomagnetism, gravity, and seismology (U.S. Coast and Geodetic Survey); glaciology (American Geographical Society); latitude and longitude (U.S. Naval Observatory); meteorology (U.S. Weather Bureau, National Weather Records Center); oceanography (Agricultural and Mechanical College of Texas); solar activity (University of Colorado, High Altitude Observatory); and rockets and satellites (National Academy of Sciences).

World Data Center B, operated by the U.S.S.R., has two subcenters. The first, at Novosibirsk, includes meteorology, geomagnetism, longitude and latitude, glaciology, oceanography, seismology, and gravity. The second, at Moscow, includes aurora and airglow, ionospheric physics, solar activity, and cosmic rays.

World Data Center C, operated by several nations in western Europe and the Pacific, has the following subcenters: geomagnetism (Denmark and Japan), aurora (Sweden and Great Britain), airglow (France and Japan), ionosphere (Great Britain and Japan), solar activity (Switzerland, Italy, Great Britain, France, German Federal Republic, and Australia), cosmic rays (Sweden and Japan), glaciology (Great Britain), meteorology (World Meteorological Organization, Geneva), and seismology (International Central Seismological Bureau, Strassburg).

Each data center will acquire a complete set of all IGY data. Each center will archive and index its compilation of data, holding it accessible to research workers. Schedules for the orderly flow of data into the centers have been arranged. These schedules vary, depending upon the nature of the data in a given discipline and upon the definition of a reasonable "lot" of data to simplify the handling problems. A "lot" of data may be one month's observations in one field or several months' observations in another.

The procedures in handling data and forwarding them appropriately involve a series of steps of the following kind: (i) collection of a "lot" of data at a field station, (ii) transmittal of the "lot" to the home laboratory of the field station, (iii) checking of field data at the home laboratory, (iv) transmittal to one of the world data centers, (v) copying of the data by one world data center for the other two and appropriate transmittal, and (vi) indexing and archiving at world data centers.

The data centers are in operation, and data are flowing into the centers. The steps outlined above lead to a peak early in 1958 and a steady 18-month plateau through at least the first six months of 1959, followed by a "clean-up" period extending probably into the first quarter or so of 1960 (*1*).

Note

1. The preparation of this narrative would not have been possible without the cooperation of many scientists and institutions engaged in the IGY program. Although some of them are mentioned in the text, it has not been possible in this summary to refer to all. The United States IGY program has only been possible because so many individual scientists as well as public and private institutions have participated and cooperated in the endeavor. Particular acknowledgment is made to members of the National Academy of Sciences' IGY staff who have helped in the preparation of this report: Stanley Ruttenberg, Phillip Mange, John Hanessian, Jr., and John Truesdale.