APPENDIX VII

THE INTERNATIONAL GEOPHYSICAL YEAR—PROPOSED UNITED STATES PROGRAM

The United States program for the International Geophysical year is described by fields below. It envisages activities in several geographical regions of concern to the Nation: (1) The Arctic and sub-Arctic regions; (2) the middle latitudes of the Northern and Southern Hemispheres, including the United States, Central America, South America, and adjacent stretches of the Atlantic and Pacific Oceans; and (3) the Antarctic and sub-Antarctic regions. The effort in these regions varies with present, sustained geophysical activities in each region and with technical needs. Existing activities of the former kind, whose results will be made available in the program, afford a substantial base for the total endeavor, and the proposed program represents those added efforts which are required for advances in geophysics expected from a major United States activity, in combination with similar special and expanded investigations by other nations.

Emphasis of much of the program is upon the Arctic and sub-Arctic, Antarctic and sub-Antarctic, a few zones in South America, and the Atlantic and Pacific Oceans. It is not necessary, in many of the programs, to add much activity within the United States, for normal operations provide this data. For example, the meteorology program includes only a few South American stations and work in the Antarctic. The data from these regions, added to those from existing Weather Bureau stations in the United States and in the North Pole regions, will provide adequate coverage for the crucial experiments planned in the Western Hemisphere. Similarly, the ionospheric, auroral, and geomagnetic programs stress the northern and southern latitudes.

ASTROGEOPHYSICAL MEASUREMENTS

Many of the most practical and everyday activities of man and society are affected and determined by astronomical phenomena. Surveying, whether of continental coast lines or real estate lots, mapping and charting of land and sea, tidal currents, magnetic compass and radio navigation, travel and commerce over land, sea, or air, radio communications, typhoons, duststorms and rainless regions are typical of the activities and phenomena that are closely linked to the sun, moon, and stars.

The sun, in particular, dominates events and activities on the earth. The sun's radiation—electromagnetic and particle—is the major source of energy for the earth's atmosphere and indirectly for all types of life on this planet. Some solar effects are obvious to the layman—the gross diurnal variations in weather phenomena, the weather changes by seasons, the temperature differences between the equator and the poles. Solar variations are not particularly important in these connections. Less obvious but of equally great significance to modern civilization are the effects of solar activity on the upper atmosphere. Unusual solar radiation, either in intensity or in kind, strongly influences the upper atmosphere and, indirectly, not only weather phenomena but radio communications, radio navigational systems, and many other civilian and military activities.

Solar activity has several time scales: Overall activity, measured in a number of ways, grows and subsides alternately in about 11 years—the "sunspot cycle." Individual active regions on the sun, sometimes marked by sunspots, have lifetimes of a few days to a few months, changing rather gradually during that time. Spurts of activity, occasionally during "sunspot minimum" but common during the high activity stages of the 11-year cycle, occur in some individual solar regions and last a few hours or a few days, with individual outbursts or flares lasting only 10 to 30 minutes or so.

Variation in solar activity on each of these time scales have been shown to be associated with terrestrial phenomena. Many details of these correlations, however, remain hazy because of the many interruptions in the record of solar activity observations. Further correlations of broad implications to science and civilization require detailed and comprehensive records of solar activity. The chief aim of the solar activity work during the IGY is to achieve this record by systematic observations of the sun, through improved coordination of the observing programs of the solar observatories of the world, and through more detailed, speedy and meaningful compilation of observations by coordinated reduction with workers in the relevant fields of geophysics.

Solar activity—solar flares, coronal and chromospheric activity, and sun spots—will be observed as part of the overall geophysical program. In particular, solar flares will be studied in order to correlate them with changes in cosmic rays, ionospheric and auroral disturbances, and meteorological phenomena. One of the immediate uses to which flare data will be put during the IGY has to do with the "Warning Service" program (see below). While regularly planned measurements will go on during the IGY, it is especially important that experiments be conducted simultaneously throughout the world during periods of unusual activity of the sun. The Warning Service will collect data from all fields, as well as solar activity, and will broadcast the imminence, onset or presence of unusual geophysical effects, such as solar flares, magnetic storms, ionospheric fadeouts and blackouts, signaling the observers to proceed with their special preestablished study programs.

The IGY also affords an opportunity to achieve a marked advance in longitude and latitude measurements. There are two kinds of longitude and latitude: Geographic and astronomical. Geographic coordinates must be used in mapping and can only be obtained for the earth as a whole by observing the moon or by measurements of gravity all over the earth, which have never been adequately obtained. Astronomical coordinates can be determined accurately only by observing the stars. While these are not useful for making maps, their high precision makes them useful for detecting a possible shift in the distance between two land masses.

The longitudes and latitudes of numerous points in all civilized countries have been accurately measured so that accurate maps of large regions have been possible. But it has not been possible to extend the surveys across the oceans because they are too wide: There are not islands enough to use as stepping stones, nor has it been possible to connect the separate networks of longitudes and latitudes with each other more accurately than 200 or 300 feet, and the location of some islands is uncertain by a mile. The moon, however, can be used as a stepping stone across oceans, using a new photographic technique that makes it possible to observe the moon with the necessary precision whenever it can be seen at night. This makes it possible to accomplish as much in a single year as could be done in a century by the older methods, provided a sufficient number of observatories, well distributed geographically, are included in the program. The observational technique consists of direct photography of the moon, the camera being specially devised to hold the image of the moon stationary among the stars while the exposure is being made. The probable error of a single observation is about 0.15 second of arc, corresponding in general to about 900 feet on the earth. Thus, 200 observations at each of 2 stations should give the distance between them with a probable error of about 90 feet. The new technique adds greatly to the precision with which changes in the speed of rotation of the earth can be measured, and the observational material obtained for this geodetic program may be expected to shed new light on the inner constitution of the earth.

METEOROLOGY

The atmosphere is the working fluid of an enormous engine which picks up heat in the tropics and discharges it in the polar regions. In the course of this complex thermodynamic process, the atmosphere creates winds and weather. Measurements of temperatures, pressures, humidities, and winds from the few hundred such stations in the Northern Hemisphere are assembled into a picture of the current state of the atmosphere, and are used to explain the existing weather patterns and to predict their changes. In spite of the large increase in number of these sounding-balloon observations in recent decades, there exist vast volumes of the atmosphere still unexplored. The relatively known portion of the atmosphere is largely limited to the lower reaches of the atmosphere in the Northern Hemisphere: The air masses of the Southern Hemisphere and of the whole upper atmosphere remain largely unknown. No marked advance in meteorology appears likely without a major international cooperative effort in this field and the related fields of geophysics.

The proposed United States program in meteorology will provide significant data in three areas: The lower atmosphere in the Northern Hemisphere, where there exist a number of stations in norcal operation; the Southern Hemisphere where strategic, temporary new stations are proposed in order to understand this largely unknown region; and the upper atmosphere from which data will be obtained in the rocket-exploration program.

The North and South Poles will be connected with a line of weather stations equipped with sounding balloons capable of going to heights of 100,000 feet or more. Stations are to be established along three pole-to-pole world lines. The data obtained thereby should provide clues as to whether southern hemispheric weather changes precede and control those in the Northern Hemisphere, or whether both these are controlled by upper atmospheric conditions (perhaps brought about by changes in solar radiation). The world line which the United States is most interested in is the 80th meridian, west of Greenwich, passing through the eastern portions of North America and the west coast of South America, making use of existing stations in the Northern Hemisphere. The northern terminus of this line is Eureka, N. W. T. at 80° N., completely equipped with weather instruments and sounding balloons. The line then passes through the joint Canadian-United States operated Arctic weather stations in the Canadian Archipelago and the Canadian stations in the Hudson Bay area, entering the United States at Buffalo. It hops along a series of United States stations, crosses over to stations in the Caribbean, and reaches the Pacific Ocean at Balboa. There the presently existing line comes to an end, well north of the equator.

It is proposed to extend this line to the South Pole by establishing eight additional weather stations—the minimum needed for scientific analysis. Five of these stations would be located along the west coast of South America and the remaining 3 in Antarctica. The only presently existing station of this kind in South America, Port Stanley (Falkland Islands), would be incorporated in the line.

Four of the proposed five new stations for South America would be located at sites already recommended for weather-aviation purposes by the International Civil Aeronautics Organization (ICAO) and endorsed by the World Meteorological Organization (WMO). These four stations are Guayaquil, Ecuador; Lima, Peru; Santiago, Chile; and San Carlos de Bariloche, Argentina. It is proposed that the United States furnish the technical guidance and specialized weather equipment, and that the respective South American countries furnish the 16 observers necessary to man the 4 stations. The fifth South American station would be located at the Smithsonian Institution solar station at Montezuma, Chile. Existing facilities and part-time assistance by resident observers there would be used to reduce the cost of maintaining this fifth station.

In Antarctica, three stations would be established: At Little America, at a point near 80° S., 120° W., and at the South Pole. These stations would complete the pole-to-pole line. The Little America station would also permit comparison with meteorological observations made by previous expeditions.

The data from this line of stations will be used in the study of various transport problems, e. g., heat, momentum, energy, and water vapor. Equally important uses will be the determination of the location, strength, and movement of the various jet streams, the study of the possible interdependence of circulations of both hemispheres, and the addition of the Southern Hemisphere circulation to our knowledge. The Antarctic observations will also shed further light on the reported differences in the wintertime structure of the upper troposphere and of the lower stratosphere between the Arctic and Antarctic regions, leading to a better understanding of the general circulation of the atmosphere.

The proposed Antarctic station near 80° S., 120° W., which introduces a slight "dog-leg" in the pole-to-pole line of stations, is chosen to permit the study of a phenomenon uncovered from weather observations made by the Ross Expedition nearly 50 years ago. Study of these records revealed the existence of air pressure waves or "surges" spreading outward from the neighborhood of 80° S., 120° W. Since the atmosphere over Antartica is known to be the coldest in the world, both winter and summer, and also has in its Ross Sea area the most persistent low atmospheric pressure belt found anywhere, it is possible that the effect of Antartica on world weather may be proportionately much greater than indicated by its size. The proposed three stations in the Antarctic, particularly that at the supposed point of origin of the waves, plus the Antarctic stations to be established by other countries will provide the needed Antarctic meteorological data.

OCEANOGRAPHY AND GLACIOLOGY

Water in one form or another covers some four-fifths of the earth's surface. Of the earth's 197 million square miles of surface, the oceans account for some 147 millions; ice sheets, ice caps, and glaciers account for another 10 million or so. The oceans are superficially well known as avenues of travel and commerce and as reservoirs of food and dissolved minerals. Glaciers are less well known—largely and simply as ice masses associated with high mountain ranges. Yet these two major features of our earth-surface environment play a critical part in man's existence and being. Both oceanography and glaciology are linked to atmospheric events. The relationship between these fields and meteorology and solar activity is particularly close. Oceanography is intimately related to weather, and there is an interplay between atmospheric and oceanic temperatures and water content. Glaciology is closely related to climatology—the longer-range changes in weather. Both are tied together in their roles as depositories of the global water budget.

Oceanography.—As in the other fields of geophysics, the study of oceanography requires the conduct of many experiments and the taking of many measurements if major problems are to be solved. These problems have to do with the nature of oceanic currents, temperature, composition and levels, and total water content. A major problem is the study of the annual cycle in sea level and the global water budget of the oceans. Although all available tide gauge and temperature data have been studied, the problem remains unsolved—because a minimum of 20 years of tide observations at a station are required to give a meaningful average, so that values in one area can be compared with values in another area taken at a different time. As much or more could be learned by synchronous measurements during one specific year. Simultaneous measurements of fluctuations in sea level are probably the most effective and the least expensive means of studying the "weather" of the oceans—i. e., the fluctuations in ocean currents with time. To be of value, these observations must extend over vast ocean areas.

In low latitudes the recorded seasonal changes in sea level are about what can be inferred from observed changes in temperature of the superficial layers, indicating a change in specific volume rather than in mass. In high latitudes, there is also a change in mass. If these changes are associated with changes in currents, the currents at mid-latitude may be essentially confined to superficial layers, whereas at high latitudes they may extend to the very bottom and are therefore not measurable by present standard techniques. Moreover recorded sea level is lower by about one-half foot in the Northern Hemisphere in northern spring and in the Southern Hemisphere in southern spring than in the respective fall seasons. From present data it cannot be determined whether this involves flow of water across the Equator or between the fringes of the ocean basins (where nearly all tide stations are located) and the central portions (where observations are inadequate).

Such problems are analogous in oceanography to those in the meteorologic program involving measurements of air flow across a meridian and across the Equator. Similarly, the solution requires synchronous global measurements, which include (*a*) observations and reduction of data from existing tide stations; (*b*) temporary tide gages or surge recorders at some 40 stations with emphasis on islands and the Southern Hemisphere, particularly the Antarctic; and (*c*) weekly temperature readings to depths of about 1,000 feet offshore from as many tide gage stations as possible. In addition to these tide and surge observations, a major study will be undertaken of the sub-Antarctic oceans. The structure and dynamics of currents and other oceanic phenomena of this region, which is little known but of great importance in several fields of geophysics, will be explored intensively.

Glaciology.—Glacier studies have given clear indications that we are now in a cycle of warming which began about 1900. It is estimated that if the indicated warming continues for another 25 to 50 years, the ice will melt out of the Arctic Ocean in the summer, making it navigable. In addition, the warming cycle, if continued, may melt enough ice now tied up in glaciers to add to the sea level sufficiently to affect the lives of millions of people living along low coastal lands. Whether this actually happens or not, the slow change of climate has already begun to show a change of storm paths and redistribution of rainfall, rendering some areas previously well-watered more arid and, in turn, bringing water to arid regions.

The objectives of the United States glaciological efforts in the IGY program will be twofold: (1) To extend the studies of glaciers on a worldwide basis in conjunction with similar efforts of other countries and (2) to coordinate the existing observations of glaciers with the varied worldwide efforts in other fields of geophysics in order to establish quantitative and qualitative indications of long-term climatic variations affecting the world as a whole. The plan includes: (1) Assembly of all available data on the variations of glaciers; (2) analysis of the data obtained to determine the extent to which glacier variations are caused by climatic change; (3) study of the hydrological economy of specific glaciers with respect to meteorological factors; and (4) studies to establish, correlate, and trace climatic trends of the past and to improve future predictions by combining these findings with those of solar and atmospheric physics.

Two major efforts are planned in the Northern Hemisphere: (*a*) Alaska. One study region will be concentrated in the vicinity of the American Geographical Society's Juneau Ice Field project. Because of the significance of data already collected in the region, conduct of the study during the IGY will be unusually valuable. (*b*) Greenland. Intensive glacial studies of portions of the Ice Cap and fringe area in Greenland will be undertaken in cooperation with Danish scientists associated with IGY. Two Antarctic studies are also planned: (*a*) Little America. The Ross Shelf is the largest sheet glacier of its type in the world and has been studied in part by American expeditions of the past. Much quantitative information is still lacking, and considerably more can be supplied by this effort. Among the major tasks will be the survey of the 400-mile front of this glacier feature for estimates of quantitative changes. Maps and aerial photographs of this region are available; and the IGY efforts, taking advantage of this prior work, should provide a major indication of the rates of snow accumulation and wastage over a large segment of the continent. In addition, the Bay of Whales area provides a vast laboratory of glacial phenomena fundamental to the understanding of glacial mechanics. (b) Satellite stations. Descriptions of the glacial conditions and snow accumulation on the high polar plateau indicate that the South Pole station affords a unique opportunity to obtain glaciological data not now known. A glacial team of three observers will be stationed at this substation. Similar work will be carried out at the station at latitude 80° S., longitude 120° W. Operation of three stations will permit direct correlation with one another as well as with the IGY glacial studies of other nations in the Antarctic.

IONOSPHERIC PHYSICS

The ionosphere is a region of rarified, ionized gas between 50 and 250 miles above the surface of the earth. Somewhat as a mirror reflects light, the ionosphere reflects radio waves and thus makes possible long-range radio communications, radio telephony, and radio navigation. The analogy between the ionosphere and a mirror holds roughly true only in terms of this reflective property, for the ionosphere is a complex, vast region of the atmosphere, fluctuating in height and depth, varying in its ionization, and importantly affected by solar activity, geomagnetic disturbances, the aurora, and perhaps by meteors and thunderstorms.

A study of the ionosphere also inherently involves a study of geomagnetism, the aurora, and solar activity. While the "normal" (i. e., closely predictable) ionosphere is maintained by solar radiation, the occurrences of disturbed ionic layers are associated with disturbances on the sun. A solar flare may be immediately followed by a sudden ionospheric disturbance. The growth of active sunspots may be followed within a few days by geomagnetic storminess and violent auroral displays. These displays, which occur in high latitudes of the Northern and Southern Hemispheres, are frequently accompanied by radio blackouts which may completely paralyze communications in these regions. Isolated meteorological or other observing stations find that although they may use radar locally, weather and associated information cannot be transmitted to central coordinating sites. This problem is one of immediate concern to the United States, particularly since the northern auroral zone lies more over North America than over any other continent.

Radio blackouts affect radio contact not only in the Arctic but in middle latitudes as well. Radio waves propagating between any two points follow the great circle distance between these points. Because of the location of centers of population in the Northern Hemisphere, most radio communication paths from points in the United States to Great Britain, Europe and Asia penetrate or come close to the auroral zone; these communication channels are also subjected to absorption and radio blackouts, and other communication paths must be sought.

Solar activity changes greatly during the 11-year sunspot cycle. During periods of sunspot minimum, the sun is quiet; the ionosphere is then relatively normal and badly disturbed radio conditions are rare. During the several years, however, when sunspot activity is high, communications are often erratic over most regions of the globe. The period chosen for the IGY coincides with a period of maximum solar activity.

Predicting the future state of the ionosphere is one of the major problems in ionospheric physics. The prediction must indicate whether or not direct radio contact will be possible, the frequencies to be employed if the possibility is good, and the alternative "radio routes" and frequencies if the probability for direct contact is low. With regard to the Arctic, the problems are many and complex, and it is equally possible to have a failure in an ionospheric prediction as in a weather forecast. Improvement in radio prognostication requires, among other things, additional observing stations in the Arctic regions, not only for the ionosphere but also for geomagnetism and for the aurora.

An intensive coordinated study and observational program in each of these fields is required. A study of the ionosphere can scarcely be undertaken from observations made in only one nation or in one portion of the world. A national network is insufficient for the prediction of conditions either over extensive geographic areas or over extended time periods. While attempts at extrapolation may be made over the "silent areas," the accuracies are quite low.

While meteorological observations at a single site are confined to the weather parameters in the general vicinity of the station, new techniques in ionospheric observations make it possible to gain information about the ionosphere thousands of miles away. This is accomplished by oblique-incidence, back-scatter probings, which in one form of the experiment can be rotated in azimuth so as to provide information in 1 or 2 circular zones whose radii may be about 600 and 1,200 miles, respectively. This new technique greatly increases the flexibility of the observational network, but a clear interpretation of the results still requires extensive comparison with the usual type of vertical incidence probings. The latter observations provide ionospheric information only in the immediate locale of the station. The use of the oblique-incidence stations capitalizes on this new observational technique and will contribute to improvements in ionospheric predictions. More intensive study, especially of the Arctic atmosphere (by ionospheric, auroral, and geomagnetic observations), will provide a new dimension for the improvement of radio forecasts.

The ionospheric physics program consists of three principal sets of investigations, involving Arctic and Antarctic regions as well as central zones in the Northern and Southern Hemispheres: (1) A series of vertical incidence soundings whereby the ionosphere is probed by radar pulses, (2) a series of scatter soundings whereby broad areas of the ionosphere are swept by radio energy of fixed and multiple frequencies, and (3) some studies of basic properties of the ionosphere layers having to do with the mechanical and atomic dynamics of the ionospheric atmosphere.

Vertical soundings.—Vertical sounding measurements of the ionosphere provide data on the vertical height of the ionosphere layers and on the critical radio frequencies. Because the ionosphere varies in space and in time, information is needed over the surface of the earth, taken regularly throughout the day and night. Automatic ionospheric instruments are used to probe the ionosphere at frequent intervals, using radar techniques. The radar pulses are transmitted vertically up and their reflections are picked up by the same device, which measures the round-trip transit time and thus permits the determination of the distance to the ionosphere.

These data from many stations over the earth are needed for an understanding of the ionosphere as a whole, for insight into the behavior of radio waves over the frequency range from 1 megacycle to 25 megacycles, and for use in the prediction of frequencies that can be used in long-range radio communications. At the present time, reasonably adequate coverage is available in the United States through its chain of stations, while excellent coverage is available in Canada, which proportionately, has a denser network of stations. Major gaps of interest to the United States exist in the Arctic, South America, Antarctic, and North Atlantic; gaps in other parts of the world, of most direct interest to other nations, will be covered by the latter; and the combined data will be invaluable in advancing basic ionospheric knowledge and improving radio communications. The United States program in vertical soundings consists of four parts: (1) Arctic and South America, (2) Antarctic, (3) North Atlantic, and (4) Data Quality Control.

Scatter soundings.—Vertical soundings provide specific data on ionospheric height in the limited region immediately over the station. Ideally, to map the ionosphere adequately would require a dense network—literally thousands in the United States alone as against the present four. To provide data over large regions, scatter sounding is used giving oblique incidence data over a large area as the antenna is rotated, actually or in effect to scan the ionosphere. Two types of scatter sounding studies are needed: Fixed frequency and multifrequency.

Ionospheric dynamics.—More data are needed on the specific properties of the ionosphere as well as on its overall behavior as a whole. The behavior of molecules and electrons in the ionosphere—in particular, molecular and electron collisions and motions—can reveal the radiowave absorption properties and temperature of the ionospheric layers. In addition to individual particle motions, there are motions of patches of ionized particles. These motions constitute ionospheric winds, whose dynamics need to be explored for basic and applied reasons. Two investigations are to be undertaken in this area: (1) Ionospheric winds and (2) cross modulation experiments.

AURORA AND AIRGLOW

The bombardment of the earth's atmosphere by electrically charged particles produces four major effects. One effect is characterized by very high speed particles which produce cosmic rays. The other three come from relatively low speed particles. Their manifestations are: (*a*) Magnetic storms, (*b*) ionospheric storms, and (*c*) the aurora, which is the luminous trace of the charged particles in the atmosphere. All three of these phenomena give us an insight into the effects of the bombardment of the atmosphere by charged particles. Comprehensive studies of these subjects not only tell us the nature of the upper atmosphere and the action of the bombarding particles, but also provide us with the knowledge needed to predict the amount and kind of disruption of radio communications, how best to circumvent it, or actually how to utilize the aurora as a means of propagating radio waves. The disruption of radio communications is felt mostly in the Arctic and sub-Arctic regions and corresponding areas in the Southern Hemisphere. Yet it is in these frozen and desolate regions that the maintenance of satisfactory radio communications is even more important than almost anywhere else—in terms both of communications and of safety.

The ionized sheets and rays directly associated with the visible aurora are directly responsible for many of the anomalous effects observed in radio propagation. For example, the density of ionization gets so large that very high frequency radio waves may be picked up at distances far beyond expectation. Thus one radio station may provide unwanted interferences to another distant one during an auroral display. But more important, at present, are the interfering effects on radio waves which cause messages to be unintelligible, or the absorption of radio waves which may be so great that no message gets through at all. The paths of the charged particles in the atmosphere may be traced through observation of aurora. Spectroscopic and photometric analyses of aurora show us not only the composition of the atmosphere at this level but also the temperature of that portion of the atmosphere and the energies of the bombarding particles.

The North American Continent is an area ideally situated to study the aurora since it is possible to have access across the auroral zone and far to the north of it on continental land masses. There are already a number of stations in North America working on auroral and airglow problems that could be integrated with a few new stations into a very efficient network to investigate these problems. In general, the network required for this phase of the program will fit well into stations required for other phases of the IGY programs. The establishment of a main base and two satellite bases on the Antarctic continent will be a major step toward the establishment of a reasonably satisfactory network of stations in the Southern Hemisphere. Two of the likely stations in the southern zone network are of particular interest. The first is MacQuarie Island, between Australia and Antarctica, which is on the same geomagnetic field line as College, Alaska. A second is a point within a few hundred kilometers of Little America that is paired similarly with Chesterfield, Baker Lake, Canada. The establishment of auroral observations at both pairs of stations is essential.

The program, requiring an orderly and well placed network of cooperating stations, is concerned with large-scale airglow and auroral phenomena. In this field there are four main problems: (1) Airglow latitude intensity profile, (2) aurora latitude spectrum and frequency profile, (3) auroral longitude spectrum, frequency, and continuity profile, and (4) Northern-Southern Hemisphere correlations. The program has 5 major aspects: Visual and special observations, radar-type observations, spectrographic patrol, photometric observations, and data reductions and analysis.

GEOMAGNETISM

Geomagetism has various important relations and implications cutting across almost all areas of study in the physics of the atmosphere. In addition to its own specific uses in surveying, navigation (including missile guidance), and exploration for minerals and petroleum, geomagnetism has broad and basic implications in the study of the ionosphere, radio wave propagation, aurora, cosmic rays, as well as other fields of science.

While the main portion of the earth's geomagnetic field originates in the solid core of the earth, practically all the fluctuations and variations of the field originate in electric currents which flow in the atmosphere. These current systems flow within the altitude range 50–240 miles, with especilly strong current over the polar caps. The interaction of the magnetic field developed by these sheet currents with the normal geomagnetic field produces the innumerable variations so pronounced at high latitudes. In addition to currents flowing around portions of the earth within ionic layers, a current is hypothesized which flows around the earth at a distance of about 20,000 miles. The magnetic field of this ring current also affects the local field and introduces further transients which also cause variations in the geomagnetic field. Because of these effects, geomagnetic records display complex fluctuations whose nature is incompletely understood.

Changes in the earth's magnetic field are closely linked to ionospheric and auroral displays. A geomagnetic storm frequently occurs simultaneously with a strong aurora and a radio blackout. To gain better insight into the physical mechanism which causes both the geomagnetic storminess and the ionospheric disturbances, it is essential to obtain more information on the interdependence between the two. More geomagnetic data must be collected, particularly at the higher latitudes. In addition to its correlation with radio blackouts in the auroral zone, the geomagnetic field portrays constant irregular fluctuations. Some thought has been given to the possibility that at least some of these rapid fluctuations are caused by the penetration of meteors through the atmosphere.

The primary objective of the geomagnetic program during IGY is to shed new light on the conditions responsible for magnetic storms and other little-understood transient effects. Almost all features of the proposed program are directed to this end, the minor exceptions being (1) exploratory rocket observations at great heights, (2) a station at Jarvis Island to shed light on certain unexplained effects of possibly great importance in equatorial regions, and (3) exploration of the practically unknown field of high-frequency magnetic fluctuations. The proposed investigations bear upon the fundamental problems of atmospheric physics.

Two new temporary observatories will be established in Alaska at Big Delta and McKinley Park, which together with the existing observatory at College will form a tripartite array for the recording of unique data bearing on the electric currents characteristic of the north polar auroral zone. Two outpost stations will be established a few miles from the College observatory for the recording and analysis of magnetic field gradients at times of magnetic disturbance. Special rapid-run equipment will be installed and operated at seven observatories. Two magnetic observatories will be established and operated at Little America and at the important, and unique South Pole site. A semiautomatic magnetic observatory at Jarvis Island in the Pacific will be established and operated for the study of daily magnetic changes peculiar to the equatorial region. Jarvis Island is near the junction of the magnetic and geographic equators. Special apparatus will be installed at four high latitude observatories, including College, for the study of magnetic oscillations in the range of 1–10,000 cycles per second, and visible-type magnetic recorders will be installed at six sites of ionospheric and auroral observations.

COSMIC RAYS

The existence of cosmic rays has been known for 50 years, but our knowledge of them is elementary. The problem is one of major importance in understanding our universe, involved as it is in both astrophysics and in understanding the structure of the atomic nucleus. Implications of the latter are highly practical matters, for cosmic ray energies are literally millions of times greater than the energies which the largest atomic accelerators can produce.

Cosmic rays are known to consist of streams of electrically charged particles—mostly protons (the positive particles of atomic nuclei) but also the atomic nuclei of heavy elements. These particles bombard the earth all the time, and they come from every direction. Their origin appears to be interstellar space, but whether the source is the sun, the stars, or some phenomenon or process of interstellar space is unknown. There are clear connections between cosmic rays and solar activity, and the earth's magnetic field and magnetic storms also affect cosmic rays.

The magnetic field of the earth is the chief instrument for analyzing the energy of cosmic rays. The cosmic rays are bent in this field in such a way that the low-energy rays cannot arrive at equatorial latitudes but tend to come in chiefly near the magnetic poles; the high-energy components arrive at all latitudes. To study the high-energy portion, observations are made near the equator. To study the low-energy portion, observations should be made in the Arctic and Antarctic regions. The connections between solar effects and cosmic rays are generally most conspicuous for the low-energy cosmic rays; thus observations in the Far North and Far South may unravel the fundamental facts of the origin of cosmic rays. Another cosmic-ray phenomenon is the large decrease in cosmic radiation often associated with magnetic storms. It appears that these storms alter the magnetic conditions in the vicinity of the earth, and that these changed conditions may either deflect or decelerate cosmic radiation. This means that cosmic rays represent a powerful tool with which to study magnetic phenomena many thousands of miles from the earth.

Perhaps the most spectacular phenomena observed in cosmic radiations have been the rapid and very large increases which sometimes occur simultaneously with eruptions of gas on the solar disc. These coincide with disturbances in the ionosphere, which may be so severe as to black out radio communications. Such violent solar flares are generally followed by magnetic storms, which can be observed by violent changes in the earth's magnetic field and which can adversely affect communication circuits. Detailed knowledge of cosmic rays requires simultaneous investigations of flares, sun spots, and chromospheric eruptions.

The question of the origin of cosmic rays remains the outstanding basic problem in this field. The particles are related to solar phenomena—in particular, to the large increases of radiation accompanying some solar outbreaks. Perhaps conditions at the surface of the sun and in the outer solar atmosphere may be such as to accelerate nuclear particles to cosmic ray energies. In other words, the sun may well behave like a giant cyclotron, vastly more powerful than any man-made reactor. The principles that nature uses in such an accelerator are unknown; the study of the origin of cosmic rays may give us the answer. Most of the basic discoveries of the short-lived mesons and other energy particles have come from studies of cosmic radiation. Such studies have blazed the trail in our understanding of nuclear forces, furnishing the impetus to the construction of large accelerators which are now being used for more detailed investigations in this low-energy range.

The program calls for investigations of three problems: (1) Exploration of the variations in mass and energy of primary cosmic radiation, (2) exploration of the variations in cosmic radiation with both altitude and latitude, and (3) investigations of the long-time fluctuations in the neutron component of cosmic rays. These studies require simultaneous measurements widely made over the earth, including the Arctic and Antarctic regions as well as the temperate and equatorial zones; they also require parallel studies of solar activity, geomagnetism, aurora, and ionospheric physics in view of the complex interrelationships of events in these fields.

ROCKET EXPLORATION OF THE UPPER ATMOSPHERE

One of the principal problems in the investigation of atmospheric phenomena has been the general difficulty of obtaining direct measurements. Until relatively recent years the maximum height attainable by sounding balloons has been some 10 to 15 miles; within the last few years this range has increased to about 24 miles. Studies in meteorology and cosmic rays have made extensive use of such balloons. However, the upper atmosphere has not been open to direct observation by these techniques, which has meant that no direct data have been available in auroral or ionospheric physics, and the only direct data in solar studies, meteorology, and cosmic rays have been restricted to the lower atmosphere.

The development of rockets during and after World War II has provided a method of penetrating many times higher into the atmosphere. Rockoons, balloon-borne small rockets that are fired once the balloon has reached its maximum altitude, have a range of 60 miles. Aerobees or ground-launched rockets, have a range of 144 miles. Somewhat comparable rockets have been developed by other nations and are to be used for similar purposes in the IGY program.

Both types of measurement, direct and indirect, are needed. Conventional measurements, which can be made readily, inexpensively and extensively, provide the large bodies of "indirect" data upon which ultimate solutions of major geophysical problems depend. Rocket measurements, which are relatively costly and difficult, provide intensive sets of "direct" data for a short period of time, and this information can be used to "calibrate" indirect data. This, in effect, permits the conversion of large bodies of indirect data into direct data. At the same time, new discoveries are possible by rocket techniques.

Some of the types of results attained by rocket explorations are the following: (1) Solar radiation of the shorter wave lengths, which are absorbed in the upper atmosphere and hence never reach the earth, has been successfully studied—for example, a rocket measurement led to the discovery of X-rays in one of the ionospheric layers. (2) Solar ultraviolet light measurements from rockets have established the variation of the ozone with heights up to an altitude of 42 miles. (3) Electric charge densities in the ionosphere and collision frequencies of the air particles have been measured directly. (4) What are believed to be auroral particles have been detected in rocket-borne Geiger counters.

The program calls for the launching of 37 rockoons and 36 Aerobees from sites in New Mexico, Greenland, Canada, and Alaska. United States firings will be coordinated with those of other nations, particularly at those crucial times of unusual solar activity. Each rocket will carry instrumentation within the very severe weight limitations, to measure several quantities: atmospheric pressure, temperature and density; the earth's magnetic field, especially during auroral displays; night and day airglow; solar and ultraviolet light and X-rays; auroral particles; ozone distribution; ionospheric charge densities; and cosmic radiation. The results of these investigations will be integrated with the results of simultaneous measurements made in each of the major fields of geophysics that represent aspects of or directly involve the atmosphere.