Fig. 1. Setting of powder charge on the Arctic ice pack during measurements of ocean depth.

Air Force GEOPHYSICAL RESEARCH

Three of the six major laboratories comprising the research facilities of the Geophysics Research Directorate of the Air Force Cambridge Research Center, Air Research and Development Command, are described here. A subsequent article will cover the other three laboratories.

THE OPERATIONAL and engineering problems encountered in acquiring and maintaining air supremacy are manifold. Not the least of these problems concerns the behavior, characteristics, and properties of the atmosphere and the related phenomena of the lithosphere and the hydrosphere which directly or indirectly influence the atmosphere, the medium in which the Air Force operates. As part of the Air Research and Development Command, the Geophysics Research Directorate of the Air Force Cambridge Research Center carries on a major portion of the investigation being conducted today to increase our knowledge of such geophysical phenomena as are pertinent to air operating techniques and procedures. The fruits of this research contribute not only to new concepts of air warfare and to the over-all effectiveness of the United States Air Force, but also to the national economy through application of results to civil aviation, agriculture, hydroelectricity, and flood control.

In order that the geophysical elements affecting the various phases of Air Force operations might better be studied, the Geophysics Research Directorate, Air Force Cambridge Research Center, is composed of six laboratories, the operating areas of which are represented by a series of concentric spherical layers, including the earth and reaching outward into space. These are the Terrestrial Sciences Laboratory, Atmospheric Analysis Laboratory, Atmospheric Physics Laboratory, Ionospheric Laboratory, Upper Air Laboratory, and Upper Air Research Observatory. The first three of these laboratories, dealing with the earth and lower atmosphere, are described in this, the first of two articles.

Terrestrial Sciences Laboratory

The Terrestrial Sciences Laboratory conducts investigations in three distinct yet related fields of geophysics: properties of the solid body and crust of the earth; interactive effects among the earth, oceans, and atmosphere; and properties of the atmosphere and oceans, using the applicable techniques and instrumentation of seismology and acoustics. A staff of twenty-four scientists engage in projects ranging from exploding TNT charges in the Arctic ice pack to interpreting complex mathematical acoustic theory. Numerous university and commercial research contracts supplement the laboratory and field work.

The Arctic research program is representative of the interrelationship of terrestrial and atmospheric studies. One outstanding project is the occupation of T-3, a floating ice island near the North Pole, for the collection of data on its physical properties, formation, composition, and motion. A corollary experimental study of the dynamics of the ice pack and glaciers overlaying the Arctic Ocean is conducted from camps on the ice or by parties landed by aircraft for short periods of intensive experiment.

Fig. 2. Reading the portable gravity meter on the Arctic ice pack north of Alaska during an aircraft landing for scientific observations.

Seismic profiling from TNT explosions determines the thickness and elastic constants of the ice, depth of the ocean, and presence of glacier crevasses. An air-ice coupled flexural wave is being investigated to enable telemetering of shock waves from a parachuted radio seismograph to an aircraft overhead. Strain gauge equipment is used for detecting tremors and internal fracturing with resultant formation of open water and pressure ridges.

Stresses such as wind and water velocity gradients, permanent ocean currents, and tides affecting the ice and causing its motion are measured and correlated with surface weather and pressure charts. Solar observations and current meter records are used to determine the extent of ice drift.

Age determination by carbon 14 analysis of ice or bottom samples will be attempted, ocean temperatures and salinities measured and variations of magnetic declination and gravitational constant recorded.

Interactive and coupling effects between the earth and air or oceans are studied in many ways. The passage of storms at sea is believed to generate small, continually-present vibrations of 3–10-second period in the earth's crust known as microseisms. Theoretical research into their modes of propagation concerns elastic wave coupling in solid and fluid media in nonhomogeneous structures. Correlation of microseismic activity with prevailing meteorological conditions is underway which may lead to new methods of tracking weather disturbances or secondary means of securing weather information in inaccessible locations. Other air-earth interaction examples are small air pressure oscillations with periods exceeding two minutes. Their velocity and direction of propagation are tracked by arrays of continually-operating sensitive pressure recorders. These oscillations are combined with upper-air and tide records. Correlation with jet streams, thunderstorms, and frontal passages has been obtained. It may thus prove feasible to track atmospheric disturbances by means of these oscillations propagated ahead of the storm center.

In the field of atmospheric investigations, one project, utilizing the methods of seismic exploration, determines temperature and wind values in the regions 20 to 100 kilometers above the surface. TNT charges are detonated on the surface. The sound, propagated into the atmosphere and refracted back by temperature inversion layers, is recorded at sites from 150 to 500 kilometers away. From the known travel time, vertical angle and azimuth of received signal, and ray paths traced by optical refraction laws, the velocity profile is determined and winds and temperatures calculated to the maximum altitude of the sound path. Using low-level meteorological conditions as a reference, the atmospheric parameters can be determined to well above the level reached by radiosondes. Studies have been conducted over latitudes from the Canal Zone to Alaska during all seasons of the year.

Atmospheric Analysis Laboratory

Recent years have seen the emergence of several broad new fields of meteorological investigation which open new and stimulating areas of research for physicists and mathematicians. In all these fields the Atmospheric Analysis Laboratory is spending considerable effort. One of the principal avenues of attack has been an effort to place weather prediction on a rational, mathematical and objective numerical basis. Solutions of the hydrodynamic equations of motion for various atmospheric models are applied to the actual prediction of the fields of atmospheric motion. Several kinds of numerical prediction systems have been developed, some of which use high speed electronic computers and others which can make use of standard IBM equipment. Research in this field is of a pioneering character where the hydrodynamicist, mathematician and synoptic meteorologist can fully exercise their specialized talents.

Recent developments in experimental meteorology testify to the rapid progress of the rational scientific approach to the vast problem of examining and explaining atmospheric motions. Experimental investigations of hydrodynamic analogues of the atmosphere have demonstrated the feasibility of producing large scale atmospheric motions in the laboratory. The re-

The present article was prepared by members of the staffs of the Terrestrial Sciences Laboratory, the Atmospheric Analysis Laboratory, and the Atmospheric Physics Laboratory of the Air Force Cambridge Research Center, Cambridge, Massachusetts.

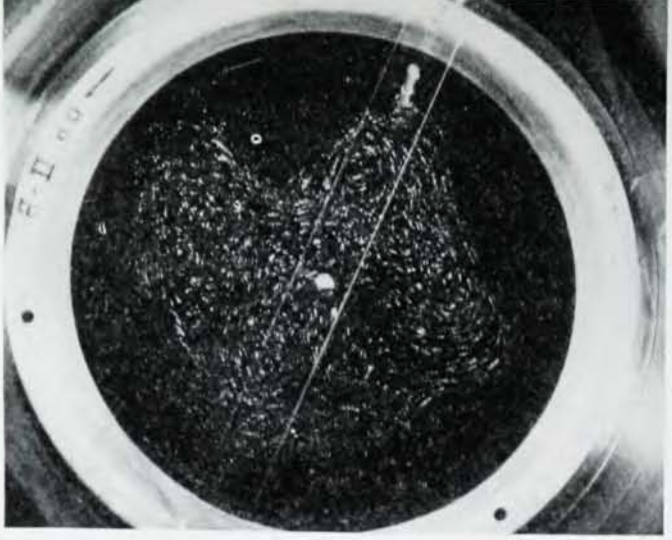

Fig. 3. High-rotation streak-flash photograph of fluid motions induced in a rotating cylinder heated at the perimeter and demonstrating a close analogy with observed fields of motion in the middle latitudes in the free atmosphere. The wavelike pattern of the streamlines and the closed vortices which are characteristic features of the flow patterns in the earth's atmosphere are to be noted. (Cylinder rotation rate is 4.81 rpm.)

Fig. 4. Low-rotation streak-flash photograph of fluid motion induced in a rotating cylinder heated at the perimeter and demonstrating a rather symmetrical vortex. This type of flow is sometimes associated with flow patterns which are observed in the free atmosphere in the tropical regions. Note the absence of pronounced wavelike disturbances. (Cylinder rotation rate is 2.92 rpm.)

sponses of fluid motions in rotating spherical shells, cylinders, and paraboloids to rotation rates and external heating conditions have demonstrated that the meteorologist can reproduce fluid motions analagous to those in the atmosphere at will and study their reactions to varying physical parameters under controlled external conditions.

In line with these approaches which parallel closely the scientific methods of other disciplines, attempts are being made to study the atmosphere in terms of its physical processes rather than in terms of parameters whose relation to the physical processes of the atmospheric system are not clearly understood. The integral requirements of the atmospheric system in so far as momentum, energy, and water are concerned are being examined to determine the manner in which the atmosphere achieves internal dynamic consistency.

Forecasting the diffusion in the atmosphere comprises still another broad avenue of research. Here applications are made of the theory of turbulence. Such applications are supplemented by a program of field experimentation requiring the design and construction of delicate equipment necessary to provide the observational information required in this field.

Woven through this broad research effort are a myriad of specialized research projects. Thus operation "Moby Dick" uses unique controlled altitude balloons set to float between fifty and one hundred thousand feet to determine the circulations in these unknown regions. On the other hand, the "Mountain Wave" project explores the nature of disturbances set up by mountain barriers by tracking the positions of performance-calibrated sailplanes to determine the nature of the air flow.

These few examples cannot begin to describe the multifold activities of the Atmospheric Analysis Laboratory where investigations range from studies of the mechanism of solar radiative processes to objective statistical methods of forecasting the motions of atmospheric disturbances.

To carry out this program, the Atmospheric Analysis Laboratory has enlisted a sizeable portion of the meteorological research facilities within this country, principally within the university meteorology departments. Within this program the applied physicist has become a vital cog, as have the applied mathematician and the statistician.

Atmospheric Physics Laboratory

The mission of the Atmospheric Physics Laboratory is to study the physical and chemical characteristics of that portion of the earth's gaseous envelope which is intimately connected with our everyday life. Since over ninety-five percent of the earth's atmosphere by weight is contained in a layer 150,000 feet thick, it is possible to study most of this area directly by means of aircraft and free balloons, and indirectly by optical techniques.

The atmosphere presents many challenges to the atmospheric physicist in the fields of electricity and magnetism, optics, heat, thermodynamics, nucleonics, and in almost all of the basic sciences. The chemist also finds a fertile field in the problems connected with gaseous composition and photosynthesis of atmospheric gases due to ultraviolet energy from the sun. Since chemical reactions cannot be brought down in a bottle from high altitudes without serious interference from the walls of the container, the chemist must make his measurements "in situ" from a balloon or rocket, or must attempt to duplicate in the laboratory the conditions which he knows exist in the higher upper air.

At the present time, both methods are being employed. An artificial sun has been constructed in the laboratory in the form of an ultraviolet vacuum monochromator having a working range from 584Å to 4000Å with which samples of atmospheric gases are irradiated and analyzed. Special ultraviolet light sources have been developed with intensities many times greater than were formerly available, and extending their ultraviolet range to 584Å by use of the helium resonance lines. At these short wavelengths there is no known material which can be used as a window, and consequently these sources are built into the monochromator as an integral part of the vacuum system with no interfering windows. A dynamic flow of helium or hydrogen through the source furnishes the discharge mechanism for the lamp.

In addition to the chemical reactions occurring in the atmosphere, there are other reactions taking place in the electrical structure of the atmosphere of which we are often unaware. The earth is continually receiving a total current of approximately 1500 amperes from our so-called "outer space." What is the source of this current, and why does the earth not charge to almost infinite potentials as a result? This is a problem for the physicist working in the field of atmospheric electricity and atmospheric nucleonics to answer. Two giant four-engine bombers have been equipped as flying laboratories to measure the ion distribution, ion mobility, electrostatic field of the earth, and the generation of ions by cosmic rays and by natural radioactive elements of the earth. One of the important factors which have appeared in the results to date is the role of the common every day variety of thunderstorm. Evidence gathered to date indicates that the charge generated by thunderstorms may be responsible for a majority of the charging current which finds its way eventually to the earth.

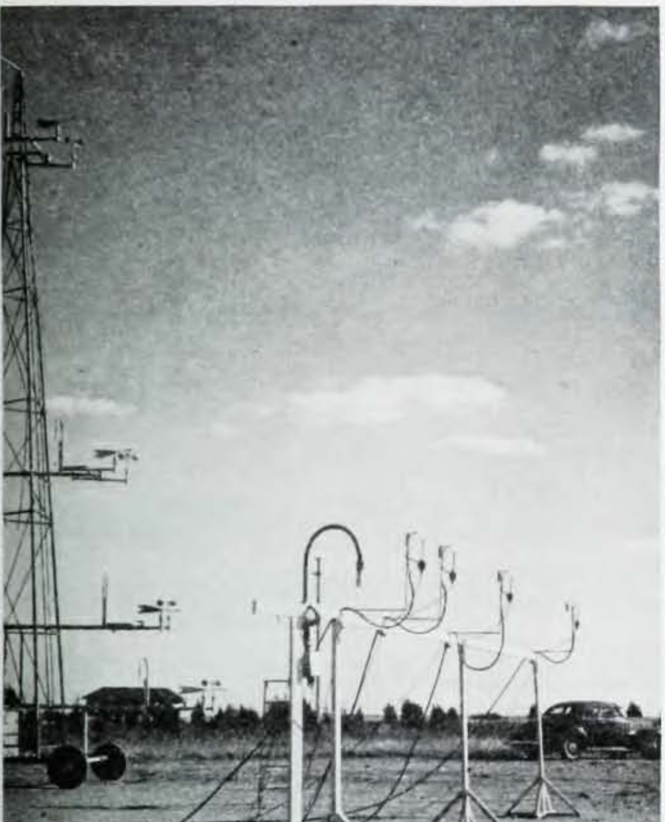

Fig. 5. A view of a typical field installation of instruments for measuring fluctuations in wind speed and wind direction. Four individual units consisting of a hot wire probe and a light wind vane are here spaced at intervals of 1, 2, and 4 m along a wood crossbar. (These are not bivanes, but their operation is similar and in the azimuth plane only.) The curved tube in the foreground houses a ventilated thermocouple that is used to measure temperature fluctuations. The portable tower in the background provides wind speed, wind direction, and air temperature data for four levels: 4.5, 9, 18, and 36 ft. The boxlike structure at the base of the tower contains pen recording apparatus on which the data are registered. The information obtained from the portable tower is used to secure mean profiles of the three quantities that are measured.

The study of air-earth currents leads logically to the thunderstorm itself, and in turn to the necessity of understanding the mechanism of cloud formation, precipitation, and cloud or fog dissipation. A comprehensive laboratory program has been underway for the last three years to understand the mechanism of nucleation in the formation of cloud droplets, the role of accretion and diffusion in the growth of cloud droplets into raindrops, the formation of ice crystals from sublimation nuclei, and the physics involved in an artificial seeding of clouds by dry ice or silver iodide. Observations are also being made in actual clouds by means of four-engine aircraft fitted up as flying cloud physics laboratories, and by means of special cloud study radars operating on extremely short wavelengths of 1.25 cm and 0.86 cm.

Since clouds obscure the vision of pilots and are one of the primary flying hazards, studies are being made of atmospheric visibility at all altitudes flown by military aircraft. At low altitudes the principal source of attenuation is clouds, dust and haze; however, at the higher altitudes now common to military aircraft, the attenuation is found to be largely due to scattering of light from air molecules known as Rayleigh scattering. Measurements made by probing the high upper atmosphere with powerful searchlight beams and measuring the light scattered from the beam at these altitudes have been carried on to elevations of forty-five miles from the earth's surface.

The atmosphere as the generator of weather and the medium of air travel is an extremely thin layer adhering to the surface of our earth. Thin as it is, it exerts a great influence upon our every day lives and is a surprisingly complicated and intricate mechanism. The more we learn about it, the more we are confronted with new problems which we have not anticipated.

Fig. 6. The installing of a precision adiabatic cloud chamber for the study of precipitation physics.