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PROGRAM OF ATMOSPHERIC ELECTRICITY SECTION

ATMOSPHERIC PHYSICS LABORATORY

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I Mission

1. The mission of the Atmospheric Electricity Section is to study and explain all atmospheric electricity phenomena associated with the lower portion of the atmosphere. To accomplish this mission, the Section is divided into three working units:

(a) Geophysical Applications Unit

(b) Physical Properties Unit

(c) Cosmic Ray Unit.

Some typical applications are:

(a) Geophysical Applications Unit.

(1) Measurement of atmospheric pollution, such as haze, smoke and smog by anomalies in normal ion distribution.

(2) Study of vertical convection currents in the atmosphere using natural ion density as a tracer.

(3) Investigation of atmospheric thunderstorm mechanisms.

(b) Physical Properties Unit.

(1) Investigation of radioactive atmospheric contamination.

(2) Study of the mechanism of ion diffusion in the atmosphere.

(c) Cosmic Ray Unit.

(1) Monitoring of height of pressure levels in the atmosphere from ground stations using Meson telescopes.

(2) Furnishing cosmic ray information of interest to aero-medical personnel for high-altitude flight.

(3) Measurements of atmospheric water content by means of neutron absorption.

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II. Program, Geophysical Application Unit

(a) Variations of Ionic Balance with Altitude.

Under ideal weather conditions the ionic balance above 2.-3 km. is controlled mainly by the equilibrium between the production of ions by cosmic rays and the destruction of ions by recombination. These two factors afford a relatively simple ionic balance equation. This has been checked by the measurement of air conductivity and known values of cosmic ray intensity with altitude up to about 10 km. A B-17 aircraft is presently equipped with suitable instruments for measuring atmospheric conductivity up to approximately 35,000 feet, and a balloon-borne device is under development to measure these quantities up to approximately 30 km. Large quantities of data are required to observe variations in ionic balance during daylight and night conditions, and to interpret data in terms of solar activity, convection currents, weather fronts, and other meteorological parameters. This is the case because even under ideal conditions the ionic balance varies appreciably, especially below 5 km., and these variations must be well understood before any super-imposed effects can be interpreted. Work on this phase is presently being conducted by members of this laboratory.

(b) Factors Controlling the Ionic Balance in the Lower Atmosphere.

In the lower atmosphere, 2-3 km. and below, a considerable portion of the ion production is due to radiations from radioactive substances in the earth; the remaining portion is due to cosmic rays. Also, at these lower altitudes, the mechanism mainly responsible for the destruction of ions is attachment of these ions to nuclei and large ions which are abundantly present; loss of ions due to recombination becomes less important in the lower regions. The amount of radioactive substances and production and distribution of nuclei and large ions will vary, independently, over wide limits with geographical location and meteorological conditions. The total columnar resistance is relatively uneffected by the resulting local variations in conductivity. Their dependence on meteorological conditions (temperature, pressure, and relative humidity) and their correlation with small ion content are being currently investigated by members of this Unit.

(c) Relation of Storms to Air-Earth Currents.

Electrical storms constitute one of the major disturbance of ionic balance in the atmosphere. This disturbance is reflected in variation of air-earth currents and electrostatic fields which have frequently measured on the ground. Large variation in potential gradient and conductivity have been observed at considerable distances from the disturbed area, at local stations where "fair weather" prevailed. Study of this phenomena will give insight into the fundamental nature and structure of the electrical disturbance and will also give information as to what constitutes an electrically undisturbed day. Phases of this investigation are presently being conducted under Contracts AF19(122)-254 and AF19(122)-467 with Dr. Holzer of U.C.L.A. and Dr. Chapman of Cornell Aeronautical Laboratories respectively. The changes in conductivity, however, will have a considerable effect on the electrostatic field and air-earth current near the earth. For proper interpretation of these effects, and any important disturbances created, their relative magnitudes must be known and behavior well understood. The vertical extent of nuclei and large ions is presently under investigation by members of this laboratory. Quantitative measurements of radiations from minerals of various samples of the earth are also being conducted. Prosecution of this project is being carried on at the request of AFOAT-1 under Contract

AF19(122)-409 with Fordham University under Dr. V. Hess.

(d) Measurement and Explanation of the Electrostatic Field Between Earth and the Ionosphere.

In the past, the tendency has been to study atmospheric electricity phenomena from measurements on the ground. As explained in the previous section, 1.(c), the results of ground measurements can be misleading due to the diversified conditions and purely local disturbances encountered. The numerous advantages of ground measurements over airborne measurements, however, warrant further investigation of the potentialities of ground measurements. To do this, information must be obtained to aid in the selection of suitable sites. Furthermore, to determine the fundamental importance of ground measurements they must be correlated with higher altitude measurements made simultaneously with air-borne equipment. This work is presently being prosecuted by Dr. Holzer of U.C.L.A. under Contract AF19(122)-254. The final objective under this contract is to definitely establish or disprove the Wilson Thunderstorm Hypothesis on the explanation for fair weather atmospheric electricity. The general approach has been to correlate thunderstorm activity with V, the potential difference between the earth and upper conducting layer which should indicate variations with supply current.

2. Applied Problems.

(a) Atmospheric Electricity Effects of Atomic Warfare.

One of the useful applications of ionic balance techniques to atomic warfare is the possibility of very rapid survey of ground fall-out after an A-bomb burst. This was demonstrated to be entirely feasible during Greenhouse. Work still remains to be done to calibrate airborne readings in terms of ground survey equivalent. Present personnel strength permits investigation into only a small phase of the work or related to the ion transport problem under the Physical Properties Unit. Ionic balance techniques can also be applied to tracking of airborne radioactive tracer material for diffusion studies in connection with any type of radioactive cloud. This was practically demonstrated on several occasions. This phase is, at present inactive due to lack of personnel.

(b) Use of Atmospheric Conductivity as a Tracer Method for Meteorological Problems.

Tracking and diffusion studies by the method described in 2.(a) can be applied to meteorology studies. Winds, convection currents and circulation of air masses can be traced for long periods. In recent tests at Los Alamos, radioactive clouds of 100 to 200 curies were released by explosions and tracked by the conductivity equipment for 75 miles. Detecting variations in ionic balance caused by large ions (e.g., those generated in industrial centers) can also be used as a tracer for the same purposes. This work is, at present, inactive due to lack of personnel.

(c) Correlation of Air-Earth Currents with Radioactive Contamination of the Atmosphere.

The cloud of an atomic burst produces high ionizing intensities extending to high altitudes. This fact may possibly be reflected in appreciable variations of air-earth currents and electrostatic fields. Investigation into this problem is being carried on as one phase of the work under Contract AF19(122)-254 with Dr. Holzer of U.C.L.A. This may constitute one of the major disturbances of ground measurements described in section 1.(d).

From a long-range point of view, Dr. G. R. Wait, formerly of

Carnegie Institution, is reviewing all previous data on air-earth currents in an attempt to set up a normal value of atmospheric conductivity which existed before the atomic energy program became active. Variations of the normal will then be studied to determine the effect of meteorological parameters on this quantity. Any deviations from the normal which cannot be accounted for will then be examined in recent records to determine whether they are produced by radioactive wastes thrown into the atmosphere. If radioactive wastes are shown to produce measurable variations in over-all ionic balance, it may prove to be a sensitive method of measuring the general contamination level of the atmosphere.

(d) Use of Ionic Balance Measurements to Determine Smoke Intensities.

It has been described in section 1.(c) how large ions and nuclei destroy most of the small ions by attachment in the lower atmosphere. Large ions are produced in any combustion process and consequently are generated in large numbers in the smoke from industrial areas. Since the visible combustion products are not necessarily the most harmful it is probable that a good measure of the harmful combustion products might be a function of the large ion concentration they carry. The large ion concentration can be measured directly with a large ion counter, or by the decrease in small ion concentration or conductivity. Work on this problem is presently inactive due to the limited strength in personnel.

(e) Maintaining Zero Net Charge on Aircraft.

A serious problem in the measurement of ion concentrations with aircraft is introduced by the accumulation of charge on the aircraft in flight. This charge creates an electrostatic field which causes the ions

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to deviate from their normal path thereby causing erroneous readings. The standard type wick discharges only partly remedy this problem. A corona discharger can be used to discharge the excess charge on the aircraft at a higher rate. If the discharge rate is controlled by electrostatic field detectors a closed loop system can be made to automatically maintain zero net charge on the aircraft. This also has possible application for reducing communication system blackout due to spurious corona currents on aircraft. This work is currently being conducted by Dr. S. Chapman of Cornell Aeronautical Laboratory under Contract AF19(122)-475.

(f) Use of Ionic Balance to Detect Air, Sea or Surface Craft.

Section 2.(d) describes how combustion products can be detected. This method might be used to detect any type craft producing combustion products in its power system. In one instance over the Pacific Ocean a ship was detected at an altitude of about 8,000 feet by a decrease of about 20% in small ion concentration in the air. The possibility also exists of detecting atomic powered craft by an increase in ion concentration. There is no active work being conducted on this problem due to limited number personnel.

(g) Use of Ionic Balance Measurements to Detect Hidden Industrial Centers.

It is obvious that the method described in 2.(f) might also be applicable for the detection of underground or camouflaged industrial or atomic centers. [illegible] inactive.

(h) Use of Ionic Balance Measurements in Prospecting for Radioactive Mineral Deposits from the Air.

No work is currently being conducted in this direction.

III Program, Physical Property Unit.

(a) Evaluation of the Coefficient of Recombination for Large and Small Ions.

The process of recombination of positive and negative ions in the atmosphere is one of the most important mechanisms by which large and small ions in the atmosphere are lost. In calculating the rate at which ions are produced in the atmosphere either by natural causes or by artificial means such as radioactivity, the data on the ion concentration must be corrected for the loss of ions by recombination. The recombination coefficient is a function of mobility, and is consequently dependent upon altitude to some extent. Various values for this coefficient are available in the literature, but the circumstances under which these coefficients are valid is not too well defined. It is planned to study the rate of recombination of ions in the laboratory using a known ionizing radiation strength and measuring the decay rate with time after the ionizating radiation is removed at pressures and temperatures of dust free atmospheric gases ranging from sea level to approximately 100,000 feet. It is hoped to develop techniques and instruments which will function eventually with the same precision in an aircraft as in the laboratory, so that these measurements can be made in the atmosphere itself. This is in an inactive phase.

(b) Determination of the Coefficient of Attachment of Small Ions with Atmospheric Nuclei.

In altitude ranges between sea level and approximately 7,000 to 10,000 feet, calculations of the rate of ion production must include the rate of attachment of small ions to atmospheric nuclei as well as the rate of recombination. At sea level and in atmosphere containing fog or cloud particles of smoke, the effect of attachment on the destruction of small ions is several orders of magnitude greater than the process of recombination. This is inactive.

(c) Mobility Spectrum of Atmospheric Ions.

In most studies of atmospheric ions, it is common to consider all ions as grouped into classifications of small, medium and large. These classifications are based upon their relative mobilities in the atmosphere. The usual number of medium ions in the atmosphere is relatively small, while the number of small ions is generally large. The number of large ions is usually significant only at low altitudes. The problem will be first attacked in the laboratory where the methods developed by previous investigators such as Frosl, Yunker, Wait and Gish will be tried. It is hoped that this preliminary investigation will result in the development of an airborne instrument which will be installed in an aircraft and used to determine the mobility spectrum of ions in the atmosphere. This is inactive.

(d) Transport of Ions in the Atmosphere.

Given the strength of a radioactive source at a given position, the rate of production of ions in the atmosphere at a distance x from the source can be calculated with some degree of success by Eve's equation $q = \frac{Qke^{-ux}}{x^2}$. Once ions are produced in the atmosphere, they may be transported from the point of generation by winds aloft. Hence, if we know the wind velocities and how long ions live in the atmosphere, we should be able to calculate how far ions should be transported in the atmosphere. Experiments conducted at Los Alamos with large radioactive sources on the ground and at Operation Greenhouse have shown that ions produced by radioactive sources may be detected at distances considerably greater than those calculated according to the above considerations. In an attempt to find out why such a discrepancy exists, work has been begun in the laboratory to determine the life-time of atmospheric ions as a function of atmospheric conditions, such as large ion content, nuclei content, etc. Then ion-detecting equipment will be installed on an L-13 liaison type of aircraft and the plane will be flown over a [illegible] curie Co^{60} source stationed on the ground. An attempt will then be made to correlate the range of detection of atmospheric ions with the life-time of the ions, wind velocities, large ion content, nuclei content and other meteorological parameters.

IV Program, Cosmic Ray Unit.

(a) Neutrons, which are formed in the atmosphere through the interactions of cosmic ray particles and the atoms of atmospheric gases, have a maximum intensity at about 54,000 feet. The neutrons have a large range, losing energy only when they make nuclear collisions. The presence of water or water vapor introduces hydrogen nuclei which cause the neutrons to lose much more energy per collision. The correlations between water content in the atmosphere and neutron intensity at ground level by means of detectors which can select neutrons of various energies are now being studied in this laboratory. Changes in the energy spectrum caused by the presence of water and water vapor will also be studied. Continuous monitoring of the neutron intensity at sea level and on Mt. Washington will be carried on in conjunction with the University of New Hampshire under Contract AF19(604)-75.

(b) Mu mesons are penetrating ionizing particles of the cosmic radiation which arise through the decay of pi mesons, also secondary particles. Nuclear theory predicts that the decay probability of pi mesons depends upon the density of the region where they are produced and disappear, and that the ensuing mu meson intensity at sea level depends in addition on the sea level pressure and the height of the region where they are produced. A directional meson telescope was constructed "in-house", and data collected for three months was correlated with nearby Weather Bureau radiosonde flights. The results show significant correlations with the height of the 100 millibar level and the sea level pressure, as expected. However, no significant correlation with 100 millibar region temperature was found. A similar investigation for lower levels in the atmosphere is being carried out at the University of Denver by Dr. Mario Iona under Contract AF19(122)-54, where three telescopes recording mesons in various energy groups are operated at different altitudes on Mt. Evans, Colorado, up to 14,150 feet.

Investigations of the fundamental properties of pi mesons causing these subsequent interactions are being conducted under contracts with the University of Michigan, Cornell University and Syracuse University. Cornell and Michigan are operating equipment far underground in order to select high energy particles, while Syracuse will deal with interactions observed at high mountain altitudes, where intensities are quite large.

(c) Measurement of Total Ion Production in the Atmosphere.

In order to provide a firm foundation for all lower atmospheric electric studies, the evaluation of ion production by cosmic rays and all other causes must be established accurately. Up to the present, experiments along this line have been somewhat incomplete, and it is desired to carry on such measurements in this laboratory using new techniques. Ionization chambers have been designed which will evaluate wall effects and measure the inherent ionizing constituents of the atmosphere, as well as take account of external cosmic and terrestrial radiations. Measurements will be made at ground level, on a radio tower and in aircraft, in order to plot ion production as a function of altitude.

V Supplementary Program.

The supplementary program is composed primarily of short range investigations which are initiated through directives from higher headquarters, participation in joint programs, or "targets of opportunity" which are in some way related to the research program of the Atmospheric Electricity program, but do not fit directly into the organized approach to the problem. Some of these short term projects are listed below as examples of typical projects.

(a) Operation Greenhouse.

The Atmospheric Electricity Section participated in project 4.6 of Operation Greenhouse at Eniwetok from February to May 1951. Two B-50 aircraft were equipped with large and small ion chambers, air samplers, air filters, scintillation counters, aerographs, field strength meters and nuclei counters to obtain as much data concerning the ion structure of the atomic cloud as possible, and to trace its movement and diffusion for three days after each shot. The results on the whole were successful, and much important data concerning diffusion was obtained as well as trajectory data which will be used as a basis of future trajectory forecasts in the Eniwetok area. Two L-13 aircraft were also equipped with small ion conductivity apparatus, and determined that fall out surveys and crater surveys were feasible from the air using air conductivity methods. Data were also obtained which pointed to the possibility that the particle size of radioactive material in an A-bomb cloud is much smaller than originally anticipated. Final report has been written and submitted to A.E.C.

(b) Project Ranger.

In the first AEC tests at Las Vegas, Nevada, the Atmospheric Electricity Section participated at the invitation of AFOAT-1 to monitor ground fall out and contamination by means of a B-17 equipped with atmospheric conductivity equipment. The monitoring flights were successful, but it was found that the speed and lack of maneuverability of the B-17 were too great for close ground support from the standpoint of flight safety. Future tests of this type will be done with small liaison aircraft such as the L-15.

(c) Project Buster.

The B-17 aircraft was fitted up with special electrostatic precipitators which were used as a particle size spectrograph to verify particle size ranges obtained in Operation Greenhouse. Although almost paralyzed by aircraft failures, the crew obtained one set of data which checked very closely with the Greenhouse particle size spectrum and pointed out the necessity for further research in this field. Final report is being written on this phase.

(d) Particle Size Distribution.

Based on the Buster and Greenhouse tests, it became apparent from the atmospheric conductivity results that a significant quantity of fission products in an A-bomb cloud are sub-micron in size and not filterable with the usual filter techniques. This poses a problem for military aircraft designers in filtering air for oil coolers and cabin pressurization. Since the problem is not primarily a geophysical one, a proposal has been forwarded to Hq, ARDC for initiating a complete study on particle sizes in an A-bomb cloud if the Air Force determines a critical need for such information. If this work is approved, studies will be made leading to a more elaborate airborne installation, and measurements will be made whenever an AEC test is scheduled in 1953.

(e) Radioactive Silver Iodide Diffusion Studies.

One of the problems confronting the cloud physicist is the diffusion and convection aloft of silver iodide from ground generators. The suggested method is to release radioactive silver iodide from the ground and trace the pattern in the atmosphere with time using atmospheric conductivity in an aircraft as the sensitive detector. A proposal has been written on this project, and if approved, an L-13 and two C-47 aircraft will be equipped to fly these missions.

(f) Land-Ocean Effect on Small Ion Conductivity.

It has been reported in the literature that the small ion atmospheric conductivity over the ocean is greater than over the land due to the absence of smoke and dust over the ocean. Measurements to substantiate this were made by Wait and Gish from the "Carnegie" over ten years ago, and were never questioned. It was also believed that above 10,000 feet the small ion conductivity was the same over the ocean and over the land. During the recent Greenhouse tests, the project 4.6 B-50 aircraft flew from Hawaii to Travis AF Base at 25,000 and discovered an approximately 15% deficiency in conductivity over the ocean as compared to the land. Local tests made in the Kwajalein Atol area indicated that at altitudes below 6,000 feet the conductivity over the ocean was greater than over land, and above 6,000 feet the reverse was true. Some attempt was made to explain this by the latitude effect of cosmic rays, but this was not completely successful. If such a deficiency in conductivity exists over the ocean at high altitudes it means that presently accepted concepts of conductivity will have to be revised, or some source of additional ionization will have to be found over land at altitudes up to 25,000 feet to account for the difference. This problem was discussed with [illegible] of the Weather Bureau, and it was found to be contrary to results that Dr. Machta obtained from his analysis of radon content of the atmosphere near the shore line of the ocean. The Weather Bureau is extremely interested in obtaining verification of these data as well as Dr. [illegible] of the [illegible] geophysical implications. A B-29 aircraft has been fitted up with a small ion conductivity chamber and is presently being flown between Travis AFB and Hawaii using a geomagnetic course for a majority of the flight to eliminate the effect of the cosmic ray latitude effect. Further tests will be predicated on whether the present tests are able to account for the observed variations in conductivity on a purely cosmic ray latitude effect basis or whether some other mechanism is demonstrated to be involved. This phase is active.

(g) Brookhaven Project.

For the last three years this laboratory has been responsible for furnishing flight facilities to Brookhaven National Laboratories and the associated universities on cosmic ray problems. Recently, Brookhaven retired from the coordination aspects, and the Cosmic Ray Unit is now responsible for reviewing all university requests for cosmic ray flights. A B-29 is available at Griffiss AF base for this purpose, and is scheduled to meet the university requirements if approved by the Cosmic Ray Unit. Requests are also made by universities for free balloon flights up to 100,000 feet carrying payloads up to 100 pounds. It is the responsibility of the Cosmic Ray Unit to arrange with Holloman AF Base through proper channels for these specialized flights and monitor them until completed.

(h) Project Rag-weed (nickname).

The 8th AF has experienced certain operational difficulties which

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are believed to be associated with geophysical conditions. In order to define this problem, air conductivity equipment has been installed on a B-36 operational aircraft and several flights made. Insufficient data make it impossible to draw any conclusions at the present time, however, these tests will be continued until a reasonable answer is obtained. This phase is active.