PROBLEMS OF ATMOSPHERIC AND SPACE ELECTRICITY

PROCEEDINGS OF THE THIRD INTERNATIONAL CONFERENCE
ON ATMOSPHERIC AND SPACE ELECTRICITY
HELD AT
MONTREUX, SWITZERLAND
MAY 5–10, 1963

EDITED BY

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WILMINGTON, MASS., U.S.A.

SPONSORED BY
THE INTERNATIONAL ASSOCIATION OF METEOROLOGY AND
ATMOSPHERIC PHYSICS, I.A.M.A.P., AND
THE INTERNATIONAL ASSOCIATION OF GEOMAGNETISM AND
AERONOMY, I.A.G.A., OF
THE INTERNATIONAL UNION OF GEODESY
AND GEOPHYSICS, I.U.G.G.

ELSEVIER PUBLISHING COMPANY
AMSTERDAM – LONDON – NEW YORK
1965

ELSEVIER PUBLISHING COMPANY
335 JAN VAN GALENSTRAAT, P.O. BOX 211, AMSTERDAM

AMERICAN ELSEVIER PUBLISHING COMPANY, INC.
52 VANDERBILT AVENUE, NEW YORK, N.Y. 10017

ELSEVIER PUBLISHING COMPANY LIMITED
RIPPLESIDE COMMERCIAL ESTATE
BARKING, ESSEX

Library of Congress Catalog Card Number 64-18510

WITH 202 ILLUSTRATIONS AND 43 TABLES

PRINTED IN THE NETHERLANDS

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MR. S. C. CORONITI

Chairman of the Conference and Secretary of the Joint Committee of I.A.M.A.P. and I.A.G.A. of Atmospheric and Space Electricity

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PROF. DR. H. ISRAËL

PROF. DR. A. KIMPARA

PROF. DR. L. KOENIGSFELD

PREFACE

This book is a report of the Third International Conference on Atmospheric and Space Electricity, held in Montreux, Switzerland, during May 1963; it contains all the papers presented, as well as the extensive discussions. The First International Conference on Atmospheric Electricity was convened in 1954, to determine the status of research in atmospheric electricity, while the advances between 1954 and 1958 were discussed at the Second Conference. The theme selected for this Third Conference was a thorough discussion of the problem areas in atmospheric and space electricity. It was conceived by the Joint Committee of the International Association of Meteorology and Atmospheric Physics, I.A.M.A.P., and the International Association of Geomagnetism and Aeronomy, I.A.G.A., on Atmospheric and Space Electricity, during the International Congress of the I.U.G.G. at Helsinki, Finland, in 1960, and it was conducted under its auspices.

That this conference was very different from most of today's conferences is reflected in this book; it was planned that most of the time should be spent in an orderly discussion of problem areas and selected papers, but only a limited time in presenting papers. To achieve this ideal goal, much thought and work was devoted to the planning and preparation of the Conference. I would like to relate here something of the background. It began with a selection of the main topics and a chairman for each of the problem areas; next came the selection of speakers to be invited for the selected topics. This was followed by a request to submit manuscripts, well in advance, and to distribute these manuscripts among the participants so that comments and criticisms could be submitted for further exchange. Thus, before the conference opened officially, each participant had read not only the papersbut also the comments of others so that he was well aware of the arguments and different viewpoints, and could prepare material for the discussion.

This extensive pre-conference work paid off and lead to lively discussions which form part of this book. At the meeting, the speakers presented a short summary of their paper and the conferees devoted most of their time, under the leadership of a selected chairman of each session, on a discussion of the problems. They were assigned the task of provoking and motivating the conferees into animated debate. As a result, the discussions were vigorous, stimulating and fruitful, indicating that everyone had done his "home work" with distinction. Needless to say, the entire proceedings were taped.

This book is a true reflection of the course of the Conference. The organization of material follows the program plan. It contains the papers, the comments made before the Conference as "short contributions", and the extensive discussions. The intrinsic value of the individual contributions will justify this compendium. As expected, prob-

lems arose in presenting the discussions. They had to be condensed to bring out the scientific facts but not condensed too much to make them "bone dry" and dull reading. To give the reader an impression of the flavor of the Conference, the individuality of the speakers and a feeling for the diversity of opinions, a verbatim report is given whenever possible. This was achieved by editing the transcript and by obtaining the speakers' approval for revisions and corrections. For the sake of coherence, some of the short contributions and all of the discussions of Session I and II were combined and inserted after Chapter II. Comments and discussions of a specific paper appear immediately after that paper.

The Joint Committee can rightfully feel that its objectives of thoroughly presenting and discussing the current problem areas in atmospheric and space electricity have been achieved. Moreover, in making this expression known to the scientific community in this book form, it may help to guide further research in this field.

In formulating and implementing this program the Chairman was assisted by the Committee and he wishes to thank those who contributed to the success of the Conference. In particular, I would like to cite and acknowledge the assistance of Dr. J. A. Chalmers, Mr. H. Dolezalek, Professor R. E. Holzer, Professor H. Israël and Dr. E. T. Pierce for their contributions in formulating the program. I am particularly indebted to Professor R. E. Holzer who served as a consultant to me. Mr. H. Dolezalek, in addition, supervised the organization at Montreux and also assisted in the editing of Chapters II and III of the proceedings. Without his efforts this conference would have suffered considerably. Mr. J. Hughes of the Office of Naval Research suggested and assisted in collating the discussions. I would also like to express my appreciation for the encouragement and assistance of Dr. G. Laclavere, Dr. W. L. Godson, and Professor L. Koenigsfeld. Finally, I would like to acknowledge the assistance of my secretary, Mrs. Betty Jane Franek, in handling the voluminous secretarial work which was associated with this Conference, and also for expertly handling the secretarial work at Montreux.

SAMUEL C. CORONITI

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ADDRESS

S.C. CORONITI

Conference Chairman, Secretary of the
Joint Committee on Atmospheric and Space Electricity

In behalf of the combined committee on Atmospheric Electricity of the International Association of Meteorology and Atmospheric Physics and the International Association of Geomagnetism and Aeronomy and in behalf of the committee members of this conference, I welcome each and everyone of you to Montreux, and to your Third International Conference on Atmospheric and Space Electricity. I say "your conference" with a deep sense of sincerity because it was, and still is, your wish and your desire to convene here today. It was your devoted cooperation and your many suggestions which facilitated the formulation of the scientific program, and the organization of this conference. Your active participation in, and your contributions to, the discussions during the next five days will insure its success, surpassing in achievements, I am convinced, those of the First and Second International Conferences.

The first conference was held under the chairmanship of Professor R.E. Holzer in Portsmouth, New Hampshire on May 19–21, 1954, and 51 scientists from 10 countries attended. The prime objectives of the conference were to bring together for the first time key scientists in atmospheric electricity from all parts of the world in order to appraise the current status of the field and to stimulate future research.

The workers in atmospheric electricity welcomed this opportunity, not only to become better acquainted with each other, but also to discuss their past, present, and future programs. That these personal contacts stimulated considerable interest in atmospheric electricity is attested by the large increase in the number of papers published subsequent to this meeting.

The conference, serving as a sounding board for the experts present, indicated that a confused and non-integrated state existed, and it exposed the complexity of the many problems.

Discussions of the papers, both in conference and in private, revealed that the three main subjects of investigation prior to 1954 had been: (*1*) the control of atmospheric electric parameters by meteorological conditions; (*2*) the source of air–earth current; (*3*) thunderstorm electricity.

Considerable theoretical and experimental efforts were devoted to the first two and, as a consequence, considerable advances in the understanding of these phenomena had been achieved. Not too considerable effort was devoted to the study of the electrification processes of the thundercloud. It was evident, from the diversified interpretation

of all the existing data, that no definite decision on a thunderstorm electrification theory could be made until more experimental data in and around the thunderstorm were available. Commenting on this problem, Dr. Ross Gunn summarized it succinctly when he stated: "There is no difference of opinion regarding the data. All I want to point out is that there are data by different observers, and interpreted differently by everyone in the room".

That was the status of atmospheric electricity in 1954. What next?

This first conference was sponsored by the U.S. Air Force Geophysical Directorate and by the U.S. Office of Naval Research. It was their continued interest in sponsoring research throughout the world in atmospheric electricity which was largely responsible for its resurgence, especially so within the U.S.

To assess the progress of atmospheric research during this period, the U.S. Air Force Geophysical Research Directorate sponsored, under the chairmanship of Dr. Leslie Smith, the Second International Conference on Atmospheric Electricity. It convened in May 20–23, 1958, at Portsmouth, New Hampshire.

I would like to digress for a moment to mention that "May" appears to be an important month for atmospheric electricity. D. Alibard performed the "kite" experiment proposed by Franklin on May 10, 1752. He discovered, as you well know, that the thundercloud was electrified. The first two conferences convened in May and now this one is convening also in May.

The second conference was attended by 92 scientists from 10 different countries. The contents of their papers reflected a substantial growth in research activity since the first conference and, furthermore, the emphasis of research shifted from fair-weather to thunderstorm electricity.

This enhanced activity can be attributed to four factors:

(*1*) Development and availability of new vehicles, such as aircraft, high-altitude balloons, rockets, satellites, and deep space vehicles.

(*2*) The development of new equipment, such as radar, telemetering, sensitive *dc* amplifiers, analogue and digital computers, and of improved technology.

(*3*) The application to atmospheric electricity of the techniques developed in other sciences, such as the use of radar and microwave techniques to investigate the generation and dissipation of charge within thunderstorm; the use of optical and photographic, V.L.F., whistler, and magnetic techniques to study the characteristics of lightning processes; and lastly, but by no means the final one, the use of solid state concepts and techniques to investigate the thundercloud electrification processes.

(*4*) The support, as I mentioned earlier, by many national governments of basic research.

I dare say, the latter looms as the most important factor.

Notwithstanding the achievements attained within this period, Dr. Chalmers, in his book on atmospheric electricity published in 1957, lists the following as still the outstanding problems: (*1*) the maintenance of the earth's charge, or the maintenance of the atmospheric electrical circuit as referred to by Professor Israël in his book published in 1961; (*2*) the origin of thunderstorm charges and techniques to measure this phe-

nomenon; (*3*) the air–earth current; (*4*) point discharge and precipitation currents, and (*5*) the physics of the lightning discharge.

The continued existence of these problems reminds us again of their complexity. They appear to defy solution. The challenge to solve the important terrestrial atmospheric electricity problems is no less exciting today than it was at the turn of the century. There is no doubt in my mind that it will be accepted by the future scientists and there is no doubt that what now appears to be inexplicable and to be incapable of solution will, using the phrase of a renown geopolitician, "with resolve" succumb to scientific attack.

Terrestrial atmospheric electricity research is "a going concern". What about "space electricity"? Space electricity was introduced to many of you present by Professor R. E. Holzer, when, during the First International Conference on Atmospheric Electricity, he asked whether atmospheric electricity measurement should be made above 100,000 ft., whether these measurements would be significant, and whether they would contribute to our overall understanding of the atmosphere. In answering these questions, Professor Fuchs of Austria was not limited by an altitude of 100,000 ft. He stated, "All that happens in the region between the lowest part of the ionosphere and the uppermost border of the ozonsphere is of outstanding interest. We have not only to understand the thermodynamical events therein, but also their origin. At the moment, very little is known about this level". (This is equally true today.) "I may call your attention to the fact that this is also the reflection level of long radio waves. Furthermore, this region is the one which regulates or controls the propagation of sferics produced by lightning flashes. If you intend to help those men who make forecast for this practical purpose and others, you must not forget to deliver to them the knowledge they need about the electrical and thermodynamic characteristics of this 80 km region. It is high time to use new and more effective means to enlarge our knowledge about this physically highly interesting region." Indeed, it is high time that the atmospheric electricity physicists recognize and accept the fact that concepts of atmospheric electricity can be, and are presently being applied to investigate the electrical nature of the lower, upper, and what is called, space atmospheres. It is high time and long overdue for the atmospheric electricity physicist to unburden himself of the constraining shackles of meteorology. He must not limit the fruits of this science only to meteorology, but rather, as Professor Fuchs states, he must bring to bear his total knowledge and experience to problems of the entire atmosphere. His knowledge and experience are critically needed. If he doesn't accept this challenge, then, indeed, he will become a ward of meteorology.

Let us examine some of the problems of the atmospheric physicist. Between the altitude of 30–80 km one encounters, electrically speaking, a void. The conductivity and electric field have been measured accurately by many investigators from the surface of the earth to approximately 33 km. The measurements of nuclei or large ions have not been made, although recent investigations indicate their presence. Above 30 km to the lower edge of the ionosphere, we go from an ion to an electron regime. At the present time, we do not have any precise data on the spectrum of ions and their variation with altitude within this region. In order to define its electrical composition with some degree of precision, it is necessary to have more accurate measurements of ion, electron, and

neutral particle densities and also simultaneous measurements of pertinent energy fluxes of the ionizing sources. Knowledge of these quantities and their variations with altitude is necessary to explain the behavior of the *D* and *C* regions of the ionosphere.

These quantities and their variability can be measured only by sophisticated atmospheric electrical techniques. Sophistication is, indeed, essential. In addition, one must modify the instrumentation techniques to take into consideration the decrease in collision frequency, the vehicle velocity which can be greater than the ion velocities, the distribution of surface electrical charge on the vehicle, etc. Once recognized, they constitute only engineering details.

The ionosphere and immediate region above it is a fertile domain for the application of the concepts of atmospheric electricity. In this domain, we must combine the electrostatic with electrodynamic concepts; in other words, we must consider the complete set of Maxwell's equations. Indeed, this trend is evident in the present day literature. We will learn more about this domain within the next few days.

The existence of electric fields between planets and in intergalactic space has been postulated but not yet established experimentally. It has been postulated that cosmic rays are produced by simple acceleration in an electric field over large distances in space. This suggestion is highly speculative. Assuming the existence of these space electric fields, one must devise new techniques to measure them or else the values of the electric field, especially *lf* or *dc*, must be inferred from other measurements. The time dependent electric field, especially *hf*, can, of course, be measured by present techniques.

Within the galaxies, there exist cosmic electrical discharges. Satellites equipped with sensitive V.L.F. and E.L.F. instruments are used to gather experimental data on cosmic lightning. It is lightning, and the fact that it is many light years distance makes it no less exciting than terrestrial lightning. It is truly space electricity. The difference, if there are any differences between terrestrial and space electricity, is one of degree. Both are concerned with potential gradients, space charge, charged generation, charged motion, density of charge, etc.

In summary, we have made much progress within the past fifteen years in atmospheric electricity. Yet, even though our pace is accelerated, our goal, i.e., our complete understanding of basic terrestrial electrical phenomena, is still at some distance. As we approach it, the excitement of finally realizing the solution or possibly raising a series of new questions will attract many new investigators to this science. This trend is evident today, especially in this conference.

During the past few years, the concepts of atmospheric electricity have been applied to the investigation and to the interpretion of various space physical phenomena. This activity will be accelerated during the next decade.

It is the purpose of this conference to bring the problem areas of atmospheric and space electricity into sharp focus. We must discuss and we must delineate, concisely and precisely, the most challenging and the most interesting of these problems. Our success in achieving these objectives will be measured by the degree to which we can motivate ourselves to dedicate our energies to solving these problems and to which we can equally motivate the young scientists to join us in our search for these solutions.

ADDRESS

GEORGE LACLAVERE

Secretaire Général,
Union Géodésique et Géophysique Internationale

Mr. President, ladies and gentlemen. It is a great honour for me to speak to you today. I do it in my capacity as Secretary General of the I.U.G.G. The President, Professor Beloussov, would have liked to address you himself on this occasion, but at present he is in Africa directing a seismological mission sponsored jointly by the I.U.G.G. and U.N.E.S.C.O. It is, therefore, in his name, in mine, and in the name of the I.U.G.G. that I address you this morning.

This Third International Conference on Atmospheric and Space Electricity is an event of great importance. I do not need to tell you of the interest that geophysicists have in your studies, and the interest which is attached to this conference. It has been most carefully prepared by Mr. Coroniti and the part that I have played myself is very small compared to the considerable effort that he has made during several months—I would say even several years—in order to put this conference on its feet.

I think that the fine weather you enjoy today must disappoint you, for there are no visible displays of atmospheric electricity. No doubt stormy weather with thunder and lightning would be a more appropriate background for your work. I think, nevertheless, that this disappointment will be largely compensated for by the pleasure you will derive in gazing upon this magnificent countryside which stretches before your eyes.

I do not want to take advantage of your time, but simply to wish you, on behalf of the President and the I.U.G.G., every success with the program on which you are about to embark.

ADDRESS

H. R. BYERS

President of the International Association of Meteorology and Atmospheric Physics

Mr. Chairman, General Laclavere, ladies and gentlemen. It is a great pleasure to me as President of the International Association of Meteorology and Atmospheric Physics to be able to attend this meeting and to have our association participate jointly with the International Association of Geomagnetism and Aeronomy in this very fine conference. We owe a great debt to the secretariat and personally to Mr. Coroniti for the superior arrangements which have been made for this meeting, and for the excellent resources which have been available to him for implementing it. Our two associations within the International Union have had a joint committee on atmospheric electricity for a number of years. It has been one of the most successful joint committees within our union as far as its scientific achievements are concerned. As we look back on the history of the meetings of these two associations concerning the subject of atmospheric electricity, we find that we started out comparing observations made at the surface of the earth from various regions of the world and from that, the picture of the distribution of the atmospheric electric properties was obtained throughout the world. Subsequently, upper-air observations were made and the picture became three-dimensional. At the present time we are, one might say, embarking on a new realm of electricity in which we leave the atmosphere and look at the problem from the point of view of space. With the satellites of the type which now are orbiting, it is possible to make various electrical measurements and to observe the phenomena which are taking place in the atmosphere. I believe that this Third Conference on Atmospheric and Space Electricity will indeed mark a new era in the history of our joint committee.