

Dr. Wilkinson

IONOSPHERIC NETWORK ADVISORY GROUP (INAG)*
IONOSPHERE STATION INFORMATION BULLETIN No. 26 **

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* Under the auspices of Commission G Working Group G.1 of the International Union of Radio Science (URSI).

** Issued on behalf of INAG by World Data Center A for Solar-Terrestrial Physics, National Oceanic and Atmospheric Administration, Boulder, Colorado 80302, U.S.A. The bulletin is distributed to stations by the same channels (but in reverse direction) as their data ultimately flow to WDC-A. Others wishing to be on the distribution list should notify WDC-A.

I. Introduction

by

W. R. Piggott, Chairman

This issue of the INAG Bulletin is mainly concerned with the report of Dr. Rishbeth's URSI/IAGA Joint Working Group on Needs for Ionosondes in the 1980's, and the report of the INAG Meeting at Seattle. In the last issue I drew attention to the full INAG Meetings to be held in conjunction with (a) the CCIR Meeting at Geneva, January 5-6, 1978, and (b) the URSI General Assembly at Helsinki, August 1-10, 1978. We hope to see as many as possible of you at one or the other, or both of these meetings. For the large majority who will not be able to attend or be represented at these meetings, now is your chance to influence the meetings by writing to the Chairman or to your local INAG member. In particular, we badly need your views on the parameters which should be interchanged internationally in the future and on whether we should attempt to simplify the Handbook. If we make changes in either of these, we shall inevitably lose some information or accuracy but may gain in efficiency and uniformity in the use of the remaining rules. *Please re-read my introductions to INAG-23 and 25 and let me have your views.*

I hope that we will be able to publish more comments on ionogram problems and to complete the ionospheric alphabet in the next issue, and *invite you to send copies of problem ionograms which you would like me to comment on for this purpose.* I must apologize to those whose queries have not yet been answered and assure them that the answers will be published shortly.

II. Minutes of Ad Hoc INAG Meeting, at IAGA Scientific Assembly,
Seattle, Washington, U.S.A., August 30, 1977Participants:

A. H. Shapley, Honorary Member, Chairman for Meeting	U.S.A.
J. Virginia Lincoln, Vice-Chairman and Secretary, INAG	U.S.A.
R. O. Conkright, Alternate member for J. V. Lincoln	U.S.A.
J. R. Dudeney, Alternate member for W. R. Piggott	U.K.
E. Essex	Australia
G. Atkinson	Canada
T. Jorgensen	Denmark
K. Lassen	Denmark
J. Taagholt	Denmark
K. Rawer	Federal Republic of Germany
M. Petit	France
R. Rastogi	India
K. Najito	Japan
L. Kolawole	Nigeria
J. Cardus	Spain
I. Ozdogan	Turkey
A. Danilov	U.S.S.R.
E. Kazimirovsky	U.S.S.R.
G. Zhrebtsov	U.S.S.R.

Apologies were received from W. R. Piggott.

The Chairman welcomed the participants and requested them to comment on the current status of their sections of the network.

Status of Network

Australia: - Cocos Island and Port Moresby have been closed.

Canada: - St. John's has closed but will re-open for special experiments in 1980. Resolute Bay, Fort Churchill, and Ottawa will continue to operate. (Note by Piggott: This is a satisfactory outcome of the exercise on the future of the Canadian network (INAG-24, p. 4)).

- Denmark: - Godhavn, Thule, and Narssarssuaq continue with routine operation. Sonderstrom is being used for special experiments on the polar cusp phenomenon. A further USAF C4 ionosonde is being rebuilt for use at Godhavn.
- Federal Republic of Germany: - The Digisonde equipment at Breisach is available on standby and is operated once a week. The station at Lindau is continuing to operate for the time being. It is possible that this station will be transferred to the German Meteorological Service, thus making its future more secure. A new NOAA advanced ionospheric sounder is being obtained and will be deployed at Tromso to operate in conjunction with the ionospheric heating experiment, to be operated there by the Max Planck Institute for Aeronomy. The ex-German station at Tsumeb was reported closed. (Piggott: This station was transferred to the South African network 2 years ago, and the ionosonde was kept operating for a routine program to provide data to meet special inquiries. Only small samples of these data have been analyzed.)
- France: - The network is running smoothly. Many stations are now operating. Since the network is close to the magnetic equator, layer tilt effects are common, and careful data reduction and maintenance of equipment are essential to make the data suitable for scientific purposes. (Piggott: The sections of the High Latitude Supplement to the URSI Handbook which discuss F-region phenomena should also be useful in the equatorial zone. Both zones show severe tilting of the surface of constant electron density in the F region, though for different reasons. The interpretive procedures are essentially similar in both cases. *Your Chairman wishes to inquire whether there is a parallel need for a set of low latitude ionograms to help their equatorial network in the way in which the High Latitude Supplement has helped the high latitude groups. Since the range of phenomena is much smaller, this could be met either by samples in Uncle Roy's Column, or, if many groups are interested, by a special issue of this Bulletin.*)
- India: - It has come to the attention of INAG that, presently, about nine stations are supposed to be operative in India, and considerable effort and money are going into their operation. However, the quality of data at many of these locations is poor as evidenced not only by long stretches of no data, but also by a profusion of replacement letters on individual days. It is suggested that the concerned scientists and their institutional heads kindly take note of this situation and put forth some more effort to make the data really useful to the scientific community, especially from the equatorial and low latitude regions of India. It should also be kept in mind that the worth of geophysical data is enhanced considerably if the data are made available quickly to the scientific community. Presently, delays of 3 to 24 months are involved. It is hoped that the time for processing and dispatching of the data can be shortened.
- Japan: - The station at Okinawa was re-opened in February 1977. The rest of the network is operational, though there are some problems in maintaining full data reduction at all stations.
- New Zealand: - The New Zealand network is operating normally.
- Nigeria: - The station at Ibadan is active. It has received a new Australian A4 ionosonde but this is not in operation.
- Spain: - The station at Tortosa is operating a routine program. Data from the rocket site at Arensillo are not reduced but sent to WDC-C1 (Slough). There is a proposal to install a station on the Canary Islands.
- Sweden: - Uppsala, Lycksele, and Kiruna continue to operate normally.
- Turkey: - A Bibl Digisonde sounder has been operational in Turkey since 1963. The data are sent to AFGL but are not available in the WDC.
- U.K. - Slough continues to operate normally. Observations are made at South Uist, during rocket campaigns only. It is probable that Port Stanley will close in 1979 unless a strong case is made for its continuance. *Those interested in data from this site should write to the Director, Appleton Laboratory, stating why they believe the station should be maintained.* The BAS stations at Halley Bay, Argentine Islands, and South Georgia continue to operate satisfactorily on a 15-minute schedule. The possibility of expanding the research at Halley Bay is being investigated. If a major additional program is started there, it may be necessary to close South Georgia to provide additional staff. An Australian A4 ionosonde is on long

loan to BAS for testing in the Antarctic environment. This is not yet operating satisfactorily but will be sent to the Antarctic for further tests this year.

- U.S.A. - Seven stations are operating: Boulder, Wallops Island, Maui, Point Arguello, Millstone Hill, White Sands, and College, Alaska. Only four parameters are reduced at the latter station. Point Arguello and College report hourly values for forecasting use, each hour. A Digisonde is now operational at Goose Bay, and data from it should reach WDC-A shortly.
- U.S.S.R. - Thirty-five stations are now operating. Of these, 28 or 30 report hourly by telex. The responsibility for the USSR network is being transferred to the Hydrometeorological Service. Dr. Besprozvannaya is in charge of a small part of the network, and Mrs. Sokoldolskaya is in charge of the rest. Dr. Danilov was asked to write an article about the USSR network and the need for real time ionospheric data. The Chairman asked if the trend for ionosondes to be attached to a country's meteorological service should be encouraged, but there was no consensus. (Piggott: a significant fraction of the network has been run by meteorological services for many years, and the new interest in possible solar influence on weather is increasing the interest of meteorologists in the very high atmosphere. Thus there has been a change from the bigger section of the network being operated by groups interested in radio communications to groups interested in meteorology, particularly in the more advanced countries. The older interest, however, still is very important for the developing countries, and this aspect of our work was stressed in the "Symposium of Opportunities in Geomagnetism and Aeronomy for Developing Countries" held as a joint IAGA/IAMAP Joint Assembly meeting, August/September 1977 in Seattle.)

URSI/IAGA Joint Working Group Report - Needs for Ionosondes in the 1980's

Dr. Dudeney reviewed the report and commented on the objectives of the special working group. He announced that the report would be discussed at a special meeting (at the Seattle Assembly) and that a resolution on the document had been prepared by IAGA Division 2. (The report, as slightly amended to include comments made at the subsequent meeting, is published in this Bulletin, page 3, together with some additional comments.)

Status of the INAG Bulletin

The INAG Bulletin is designed to serve the networks, and contributions are requested from network operators, administrations, and scientists using network data. The Chairman stressed the importance of noting and responding to italicized passages in the Bulletin. At the present date 425 copies of the Bulletin are sent to 214 addresses. In view of the number of corrections which have been made to the Handbook (UAG-23), it is proposed to publish a special Bulletin which will reprint Chapters 1 - 4 of the Handbook. (These are the chapters most used by the operators, incorporating all clarifications and corrections to date, with corrections to the remaining chapters.)

Future Revision of the Handbook and Review of all Parameters

R. Conkright, who discussed the problems encountered during his visits to France, U.K., and South America, noted that it was time to re-examine the parameters to be scaled on a global basis. He felt that many of the special cases which occur relatively rarely confused the average operator and that scaling of some of the phenomena should be restricted to particular geographic latitudes, thus limiting the amount to be learned by the average operator. Particular points which should be discussed include whether it is worthwhile recording f_{min} for every hour at stations where this parameter is not meaningful, and whether the rule to insert values for all hours in the Es tables is justified, particularly as the rules are confusing to many users. He felt that the status of f_{xI} and types of Es as global parameters should be considered, and raised the question of the value of $h_p F_2$. (Piggott: $h_p F_2$ is not a recommended parameter though some stations continue to record it for historical reasons. Essentially the same information is given by the $M(3000)F_2$ factor.) Conkright felt that the descriptive and qualifying letter symbols should also be reviewed. (Further discussion of these points will be found in INAG-25, page 6.)

Conkright suggested that the Handbook should not be rewritten, but a scaling manual should be published. This should be in two parts:

- (a) An introduction to ionospheric physics for scalars, subdivided into midlatitude, high latitude, and low latitude scaling rules (these sections to be prepared by expert scalars from the appropriate regions and edited by W. R. Piggott).

- (b) Detailed scaling rules for local use. (Piggott: This is clearly one possible solution, though, to my mind, it may involve considerable duplication. Strictly, we have three cases:
- (i) Interpretation of ionograms when ionosphere is horizontally stratified.
 - (ii) The interpretation when the ionosphere is tilted.
 - (iii) Special phenomena which normally occur only in limited areas.

We would like to invite further comments, as the amount of effort available for the preparation of international handbooks is relatively limited.)

The Chairman stated that now that we have had two solar cycles of detailed analysis of ionograms, it would seem to be a good time to simplify the worldwide rules. There was little discussion of this item, though Dr. Rastogi stated that his group was using f_{xI} and Professor Rawer was against removing the Es types. (Piggott: It is very difficult for INAG to know what the consensus is on this type of problem, since those using different parameters are often not at the INAG meetings. In general, any simplification involves losing information, but we should be prepared to accept this if the gain in information does not justify the effort involved.)

Status of Ionosonde Development

The British Antarctic Survey has an Australian A4 ionosonde on long-term loan. There have been problems, owing to inadequate signal-to-noise ratio with this equipment under U.K. conditions, which they are attempting to solve. The equipment will be tested in Antarctica, where noise is much less, during the next year.

The USSR is designing new equipment which should be available in 1979. This combines vertical incidence and oblique incidence soundings. Some of these will provide a digitized output but will also have a standard 35-mm film output.

The NOAA digital ionosonde in the U.S.A. has not reached the testing stage. At present two are under construction and two more are expected to be built in the future. This is an exciting machine capable of many advanced types of measurement, since details of the phase amplitude and time delays of all reflected signals from an array of antennas can be recorded and analyzed in an internal mini-computer. The output is fully digital and computer compatible though, of course, conventional ionograms at any desired gain level can be produced from the basic data if required. It is hoped that the monitoring model based on the same techniques can be produced but no money is at present available for this development. Lowell Institute Digisondes are now deployed at Freiburg, Dourbes, Torino, Athens, and Istanbul. Three more are being installed in Rome, Sicily, and Greece.

The new Finnish ionosonde is performing excellently at Sodankyla and Uppsala.

The Japanese ionosondes are being replaced by a solid-state step-frequency model.

New oscillators have been installed on the C3's and C4's at Greenland stations, and these have also been converted to record backscatter on 12.7 MHz.

The Australians at La Trobe have three ionosondes; a digital receiver has been designed for the C3. They also have a phase path ionosonde and a chirp sounder for backscatter measurements.

U.K. Ionospheric Data Entry System

The British Antarctic Survey is developing a system which will enable routine ionospheric data to be produced in computer-compatible form during primary scaling and will free the scaler from preparing the daily worksheet by hand. Instead, the data are entered via a keyboard and then processed using a micro-processor. This assures that the scaling rules have been met, challenges inconsistent entries, types the daily worksheet on a teletype, and writes data to a storage medium (either paper tape or cassette). Mistakes can be corrected either during scaling or on review after the daily worksheet has been completed. The equipment costs about £1000 using paper tape and approximately £1500 with cassette storage.

Ionograms for Mapping Ionospheric Boundaries

The Chairman's suggestion (INAG-25, p. 4) that a group of scientists be invited to study ionograms at WDC-C1 for investigating the mapping of magnetospheric boundaries has not as yet proved possible. The British Antarctic Survey is collecting ionograms for Southern Hemisphere stations for this purpose as occasion allows. The group reaffirmed the Boulder recommendation on the monitoring of the auroral oval: "It was suggested that INAG should explore the possibilities of accumulating ionograms for a given month from stations near the auroral oval at World Data Centre C1 where one or two invited scientists could determine whether auroral oval phenomena can be identified and followed using conventional ionosonde techniques."

Professor Rawer suggested that the dates of magnetospheric boundary crossings be obtained from the AEROS experimenters and that a search be made at those times for ionospheric signatures. It was recommended that the paper on this subject prepared by W. R. Piggott for CCOG be reproduced in the INAG Bulletin (CCOG Handbook for the IMS, December 1976, pp. 35-41, 98). This document is reproduced on p.15 of this Bulletin.

Data Usage

The continuing wide use of ionospheric vertical incidence data is clearly indicated by the demands on the World Data Centers for such data. A significant number of stations also circulate station booklet to interested groups, in which case the demands from the Data Centers are decreased. During the past year 27,500 station-months of data have been distributed by the WDCs as follows: WDC-A, 10,000; WDC-B2, 9,000; WDC-C1, 7,000; and WDC-C2, 1,500. This implies that, on the average, each station was used at least 10 times during the year. For those interested in the details of the usage of stations, detailed usage reports are available from WDC-A and WDC-B2. The data most requested were those from Wallops Island, Huancayo, Moscow and Slough.

Special Programs of Analysis

There are a number of stations in the world which operate regularly but only analyze their data for special events or for special requests, and there are even more that operate on an intermittent basis, e.g., for special intervals, or during rocket campaigns, etc. Scientists are reminded that INAG and the WDCs would be happy to assist them in arranging to obtain data from such stations or to arrange special programs of analysis.

INAG Publicity and Use of INAG Bulletin by Other Than Vertical Incidence Soundings Network

This meeting at IAGA had been arranged primarily to enable scientists interested in aeronomical problems which could involve ionospheric soundings to make contact with the ionospheric network community and to make their own needs known. In particular, the gap between those who produce ionospheric data and those who use it is getting wider with time so that it is difficult to convince the Administrations that the data are needed, and difficult for the producers of the data to alter their procedures to match the changing needs of the science. The Chairman suggested that few outside scientists knew much about the acquisition of synoptic data and that articles about INAG should be sent to the *URSI Information Bulletin*, *IAGA News*, *IUGG Chronicle*, and *IMS Newsletter*. He also suggested that INAG should make direct contact with the leaders of other systematic monitoring networks before the Geneva formal meeting to invite them to use the resources of INAG. For example, the riometer network, ionospheric absorption network, drift network, and the numerous stations making total electron content measurements from satellites would appear to be good candidates. (Piggott: INAG has made several attempts in the past to interest the other synoptic networks in using the INAG Bulletin for discussion or dissemination of programs. A few of the leaders have, in the past, sent programs to the Chairman, and these have been reproduced in the INAG Bulletin, together with programs obtained from other sources. However, the majority of Chairmen of such groups have not replied to letters sent to them by the Chairman of INAG.)

Announcement of 1978 Meetings

It was announced that formal meetings of INAG will be held at Geneva, January 5-6, 1978, and during the URSI General Assembly, Helsinki, August 1978. *Many points have been raised in the last few INAG Bulletins and in particular in the Chairman's introductions and the reports and the minutes of INAG meetings. It is now urgent that INAG receives any comments which you wish to make on these points so that the Agenda for these meetings can be arranged.*

Membership

One or two members of INAG are retiring from active work with the networks, and it is time that INAG should consider revising its membership. While formally the membership of INAG must be approved by the sponsoring Commission of URSI, it has always been URSI policy that INAG members should be appointed in their personal capacities in the interests of the network and community, as a whole. Thus, in practice URSI has usually depended heavily on the advice of INAG for future replacements. It has always been a principle of INAG to try to select members from areas as widely separated as possible with special stress on candidates with links with a number of stations. It was suggested that, in view of its large network, the USSR might be requested to suggest a replacement for Mme. Mednikova, if she wishes to retire. (Piggott: On behalf of INAG, I would like to invite comments on INAG membership from the community as a whole. We do not wish INAG to become a closed, self-perpetuating Committee unless this is clearly to the advantage of the network as a whole.)

Concluding Recommendations

At its next formal meeting, INAG should consider resolutions on the value of continuing the ionosondes at Ibadan and Port Stanley. The problem of establishing a training program in Africa needs examination.

III. Report of IAGA/URSI Joint Working Group: Needs for Ionosondes in the 1980's

by

W. R. Piggott

The following report is the result of the work of a group of scientists set up to estimate the needs for a future ionospheric network as seen by the scientific community. The Working Group felt that its report would carry more weight if it was largely independent of INAG which represents in a special sense the interests and needs of the community who produce the data. It is thus a general policy document in which detailed considerations of particular research problems have not been considered.

In order to help the Administrations who operate ionospheric stations to appreciate more fully the particular demands on the data of their stations, we, as INAG, need to identify particular active projects. We should also bear this in mind when attending regional and other specialized conferences where the work of the network is appropriate. Thus, for example, one would expect the Equatorial Aeronomy Conference to identify chains of stations needed for study of equatorial phenomena and to make proposals for new stations. Similarly, we would hope that the high latitude people would consider the chains of stations needed to monitor high latitude phenomena. I am conscious of some gaps. For example, the optimum disposition of stations for monitoring movements of magnetospheric boundaries does not appear to have been considered in any detail and, as pointed out by Professor Rawer and Dr. Bossy when this report was discussed at IAGA, the special interest of some European scientists to exploit the very close network of ionosondes in Europe has not been specifically mentioned. I am sure that there are several other cases where active research is not known to those responsible for maintaining the stations. I understand, for example, that the Canadians were very surprised at the degree of interest in data from their stations and really only decided to keep them operating because this interest was known (INAG-24, p. 4). I hope, therefore, that the publication of this document will provoke some discussion and correspondence through the INAG Bulletin. If you wish to use ionospheric data, remember you can only rely on it continuing if your needs are known and brought to the attention of the Administrations responsible for the stations. There will be a chance for INAG to put forward comments on this report when it is considered by URSI at Helsinki in August 1978. *Please act soon so that we have time to form a consensus.* The report that follows was presented to IAGA Division 2 by Dr. J. Dudeney on behalf of Dr. Rishbeth. The original text has been slightly amended to meet comments made at that meeting and will go forward in its present form for presentation at URSI.

In view of the report, IAGA Division 2 (Aeronomy) passed Resolution No. 2, which is reproduced below:

"IAGA, *recognizing* that ionosondes continue to have an important role to play in monitoring the earth's environment, *recommends* that a global network of ionosondes should be maintained throughout the 1980's, and that efforts be continued to modernize the equipment in use and to open new observatories at locations essential for research, and *urges* that responsible authorities, before deciding to close an observatory, invite comment from the scientific community through the Ionospheric Network Advisory Group of URSI on whether the observatory is of special importance."

Note, in particular, that this gives general support to the network and requests INAG to provide comments from the scientific community when it is proposed to close stations.

NEEDS FOR IONOSONDES IN THE 1980's

REPORT OF AN AD-HOC WORKING GROUP

SET UP BY THE

IAGA/URSI JOINT WORKING GROUP

ON THE

STRUCTURE & DYNAMICS OF THE THERMOSPHERE, IONOSPHERE & EXOSPHERE

AUGUST 1977

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FOREWORD BY CHAIRMAN

This Working Group was set up to study the needs for extensive routine sounding in the 1980's. Such a study is timely for several reasons. First, when the present intensive effort of the IMS is over, upper atmosphere science will enter a new phase, probably marked on the one hand by consolidation and on the other hand by further large-scale environmental studies of the whole upper atmosphere. Second, it is likely that some ionospheric sounders have been kept going to meet IMS needs, some with ageing instruments, and could not continue thereafter without extensive (and expensive) re-equipment. Third, the development of modern computer-controlled sounders with sophisticated data handling bring prospects of a new kind of ionospheric sounding. As the science develops, such studies ought to be made from time to time. A major URSI/STP Report was issued in 1969, and some of its conclusions still hold.

This report is intended as a policy document, and the Working Group hopes it will be useful as such. It does not seek to encroach on the work of the Ionospheric Network Advisory Group and the new International Digital Ionosonde Group, INAG and IDIG, both of which have an important part to play in developing the future of ionospheric sounding. It has had to be compiled without detailed knowledge of what the major problems of upper atmosphere science will be in the 1980's. Few scientists would attempt to specify such problems in detail many years ahead. Inevitably, therefore, the contributors tend to think in terms of the present major problems (some of which will still be unsolved in the 1980's), and they cannot specify in detail what experimental programs will need the support of ionosondes. The report is called "Needs for Ionosondes in the 1980's" in the hope that its conclusions will be valid for a few years at least: one cannot hope for more.

I should mention that, in using the convenient term "network" to describe the distribution of ionosondes, the Group recognizes that, as W. R. Piggott says, "...the network is not a centrally planned organization... it is a free association of a large number of independent groups." I emphasize too that the Group was not set up with any prior intention of maintaining a *status quo*.

In their contributions to the Working Group, the members (in my view) spoke as individual scientists, not as official representatives of their institutions or countries. I would like to thank them for their work. Any new and useful ideas in this document belong to them and the other scientists in many countries whom they consulted. I hope that my editing does justice to them. If it does not, or if the Group has missed vital questions and answered the wrong ones, the fault is mine.

H. Rishbeth

1. Membership of Working Group

A. Giraldez, LIARA, Buenos Aires, Argentina
 J. A. Gledhill, Rhodes University, Grahamstown, South Africa
 J. O. Oyinloye, University of Ibadan, Ibadan, Nigeria
 {N. P. Benkova, IZMIRAN, Akademgorodok, USSR jointly with
 {A. S. Besprozvannaya, Arctic & Antarctic Research Institute, Leningrad, USSR
 R. S. Unwin, Geophysical Observatory, Christchurch, New Zealand
 J. Oksman, University of Oulu, Oulu, Finland
 R. Raghavarao, Physical Research Laboratory, Ahmedabad, India
 J. R. Dudeney, British Antarctic Survey, Cambridge, England
 D. C. Cole, Ionospheric Prediction Service, Sydney, Australia
 E. L. Hagg, Communications Research Centre, Ottawa, Canada
 N. Wakai, Radio Research Laboratories, Tokyo, Japan
 L. Bossy, Institut Royal Meteorologique de Belgique, Brussels, Belgium
 J. R. Nisbet, Pennsylvania State University, University Park, PA, USA

Convenor and Editor of Report:

H. Rishbeth, Appleton Laboratory, Slough, United Kingdom

2. Questions for Study

- (1a) The geographical distribution of ionosondes after the IMS.
- (1b) The future need for routine ionosonde operation.
- (1c) The future need for routine hourly scaling and publication of parameters.
- (1d) What parameters derivable from ionograms are most important to geophysics.
- (2a) Is a large number of simple ionospheric sounders more or less valuable than a small number of very sophisticated devices?
- (2b) Should unmanned sounders with suitable telemetry be used in remote regions?
- (3) Is ground-based ionospheric sounding likely to be needed in conjunction with future satellite experiments?
- (4) To what extent should other types of instrument *supplement* or *replace* ionosondes for routine monitoring: e.g., oblique incidence sounders; polarimeters using satellite transmissions; polarimeters using cosmic radio noise; HF Doppler sounders?

Members were invited to comment on these questions, though no substantial modifications to them were made. Members were strongly encouraged to make additional comments and suggestions beyond their answers to the specific questions. Many of them did so, and such comments have been very useful in compiling the report.

3. Mode of Operation of the Working Group

Following the initial proposals for setting up an ad-hoc group on the subject of ionosondes, H. Rishbeth (Chairman of the URSI/IAGA Joint Working Group on "Structure & Dynamics of the Thermosphere, Ionosphere and Exosphere") had informal discussions and correspondence with individual URSI and IAGA scientists about what the group should do and how it should be composed. Subsequently, the invitations to join the group were sent out in November 1976, together with a list of proposed questions. Acceptances were readily forthcoming and were notified to all members; the detailed contributions were received by the Chairman in April and May 1977. A draft report, together with copies of the members' contributions, was circulated to members for their further comments, which were taken into account in the writing of the final report in July and August 1977. At no time did the Group actually meet, so the Chairman carries the responsibility for ensuring that a variety of views are reasonably well accounted for.

It should be stressed that the members in no sense acted as national representatives (except insofar as the Soviet IGC Committee nominated the members from the USSR). They were chosen to represent a wide geographical coverage and a variety of specialist interests. They were encouraged to consult other people in their countries and geographical regions, and (if they wished) other scientists with similar specialist interests anywhere in the world. Having been supplied with the membership list of the Group, members were left to define for themselves what

geographical region they should cover; they were also free to decide how to go about procuring the information for their contributions. Some members devised their own questionnaires but, as a matter of policy, the Chairman did not issue any general questionnaire himself through IAGA, URSI, or other channels.

In addition to the Members' contributions, the Chairman would like to acknowledge helpful personal correspondence received from: J. D. Whitehead, W. R. Piggott, C. M. Minnis, A. K. Sinha, J. G. Roederer, K. Rawer, K. D. Cole, J. V. Lincoln, C. G. McCue, and J. W. Wright.

GENERAL REMARKS ON THE NEEDS FOR IONOSONDES

4. Ionosondes provide a cost-effective way of monitoring an important part of the earth's environment. They produce a wealth of information from a substantial interval of height and on a global scale that hardly any other technique can match. The long sequences of data, extending over three or four solar cycles in some cases, are a permanently valuable scientific asset that should not be ended.
5. A network of ionosondes will be needed in the 1980's as part of the large-scale experimental programs that will take place to improve man's knowledge of the whole interactive system of the upper atmosphere. Current ionosonde data will be needed to support these programs. The existence of many years' past data at many sites, however valuable, is not a substitute for simultaneous data.
6. In particular a network of ionosondes is needed:
 - (a) To study the development and propagation of large-scale disturbances of many types in the upper atmosphere. For this purpose, north-south chains of stations covering substantial ranges of latitude are necessary.
 - (b) To study smaller-scale and day-to-day variations.
 - (c) To provide reference data at fixed locations for satellite, rocket, and balloon experiments.
7. Bearing in mind that many users of the ionosphere for communications purposes have their own specialized sounding equipment, the needs for ionosondes to aid communications seem to be limited to:
 - (a) Monitoring of solar-cycle and other long-term variations.
 - (b) Real-time data from key sites to aid forecasting of short-term disturbances.
8. Reports from the World Data Centres show that the demand for ionospheric data continues unabated. Although this demand cannot be equated to the need for new data several years hence, it does provide evidence of a high level of activity in ionospheric science.

THE FUTURE IONOSONDE NETWORK

I. Geographical distribution: Question 1a

10. At present about 150 sounders are routinely operated as part of the "network," but they are not ideally distributed.
11. To meet the scientific needs there should ideally be
 - (a) North-south chains of stations from pole to pole with close spacing (about 5°) within $\pm 25^{\circ}$ of the magnetic equator, wider spacing (about 15°) in temperate regions, close spacing (less than 10°) in auroral regions.
 - (b) Several stations in the Arctic and Antarctic, so distributed as to give adequate coverage of geographic and geomagnetic parameters.
 - (c) Extra stations to fill large gaps, especially in oceanic regions.

12. Bearing in mind the facts of geography, particularly the distribution of land masses, there should remain:
 - (a) Three full chains, approximately at longitudes 0 - 30E; 120 - 150E; 45 - 75W.
 - (b) Partial chains, for example at about 75E (mainly N); 170E (mainly S); 105W (mainly N), supplemented by some stations in the opposite hemisphere.
13. The spacings given above naturally contain compromises; some investigations would require a localized denser network (para. 6(b)).
14. The communications needs (para. 7) can probably be met by the above (paras. 11, 12) if supplemented by extra equipment (e.g., oblique sounders, for particular paths).
15. After the IMS it seems likely that the existing network will be reduced by economic factors to about the minimum that would meet the scientific needs: it should not be reduced further.
16. To meet the scientific needs, all existing stations in low latitudes and the Southern Hemisphere should be retained. The responsible administrations should be encouraged to keep such stations in operation.

II. Routine operation and publication of data: Questions 1b, 1c

20. Routine operation is essential for the data to be scientifically useful and for quality control. The data will only be widely used if they are widely available, so regular publication of at least some data from each active observatory is necessary.
21. Hourly data are sufficient for publication as a general rule. Quarter-hourly operation is often desirable to aid reliability of interpretation, with 5-minute operation on occasions (particularly at high latitudes) even if such data are not routinely scaled and published.
22. Information on what further data are available from each observatory (in addition to what is routinely distributed) should be available, preferably distributed with the routine data.
23. The uniformity that has been achieved in scaling and publishing ionospheric data is most valuable and should be preserved.
24. INAG has played a vital part in coordinating ionosonde activities and should be given every encouragement to continue its work.

III. Important parameters: Question 1d

30. The major parameters for geophysical use are, roughly in descending order of importance:
 - (a) Critical frequencies foF2, foE, foF1.
 - (b) MUF factor.
 - (c) Es information.
 - (d) Spread F information.
 - (e) fmin or fm2.
 - (f) h'E, h'F, or h'F2.
31. The list of para. 30 implies that current practice is generally satisfactory, though opinions naturally vary as to the actual order of importance.
32. The value of uniform practice is again stressed, even though for some studies (notably of sporadic E and Spread F) the requirements vary with location.

33. Studies of special events, and fine and hyperfine structure, will need more data than can be routinely made available. In particular, specialist research needs copies of actual ionograms so these should continue to be readily available.
34. Phase and amplitude information can enhance the value of ionosonde data and should be provided in digital form if possible.
35. Where advanced ionosondes giving digital output are in use, the routine production of N(h) profiles should be considered, or at least the recording of sufficient output for that purpose.

IV. Types of sounders: Questions 2a, 2b

40. Any ionosonde used regularly as part of the network outlined in paras. 11-12 should preferably be able to measure all the parameters listed in para. 30.
41. It does not seem cost-effective to develop 'very simple' sounders capable only of measuring a few of the basic parameters.
42. There would be some interest in the development of unmanned sounders for operation in remote areas provided that they could be made extremely reliable, and that power and telemetry could be provided economically.
43. Such sounders might provide real-time data from remote regions that could be very valuable for some communications purposes. However, in terms of development and operating costs manned sounders may be more economical than unmanned ones.
44. Advanced computer-controlled sounders will make an important contribution to any future network, capable of providing routine parameters (para. 30) as background data besides N(h) data and dynamical information.
45. Nevertheless individual administrations can only provide equipment as dictated by their particular needs and resources, and conventional sounders will continue to play an important role in circumstances where advanced sounders cannot be provided.
46. Data-scaling costs may be decisive in the choice of instrument for a given location. A station will only contribute effectively to the network if its data are properly reduced and published (para. 20).

V. Use with satellites and specialized facilities: Question 3

50. Ionosondes are certainly needed to provide reference data for the satellite observations that will be made in the 1980's. The ionosondes' ability to produce routine data over a substantial height interval at fixed locations is particularly useful for this purpose, especially in resolving temporal variations from spatial ones.
51. Examples of satellite projects that are likely to require extensive ionosonde data are the Spacelab/Shuttle; the Canadian High-Altitude, Low-Altitude Measure satellite (HAM-LAM) and Search & Rescue satellite (SAR-SAT); meteorological satellites such as Nimbus and ITOS. In some cases there may be requirements for data in real time.
52. Ionosondes will continue to be needed at special facilities, such as rocket ranges and incoherent scatter radars. Some of these facilities will possess sophisticated ionosondes, which could be valuable parts of the global network if suitable routine operation can be arranged.

VI. Use of other instruments to replace or supplement ionosondes: Question 4

60. No other type of instrument can *replace* ionosondes because of the wealth of data they produce, though many other instruments can and should be used to *support* and *supplement* them.
61. Oblique incidence sounders can provide valuable supplementary information, especially for communications purposes.
62. Given suitable satellites, polarimeters using geostationary satellite transmissions provide a continuous monitor of total electron content especially useful for the study of disturbances. They are best suited to low and middle latitudes.

63. A good standardized routine measurement of ionospheric absorption is needed, f_{min} or f_{m2} not being really satisfactory. Riometers (A2) are useful for this purpose at high latitudes; pulse absorption (A1) should be more widely used at middle and low latitudes.

CONCLUSION

70. It is concluded that a substantial network of ionospheric sounders will be needed in the 1980's to support the planned large-scale scientific investigations of the upper atmosphere, and also for communications via the ionosphere, as specified in paras. 5-7.
71. The needs will be for current data, and cannot entirely be met from past data.
72. The need for ionospheric data in the Southern Hemisphere and at low latitudes is such that existing stations should be retained.
73. With that proviso, the specifications given in paras. 11-12 could be met by the existing network allowing for some anticipated reduction.
74. Before a national administration closes any station, the scientific community should be invited to comment, through INAG, especially in relation to the following criteria for identifying stations that are especially valuable:
- (a) Those that have an unbroken run of good quality data extending over some decades, particularly in view of their potential use for monitoring long-term and man-made changes.
 - (b) Those forming part of 'chains,' generally north-south, which can study the propagation and development of large-scale geophysical disturbances.
 - (c) Those in geophysically interesting regions, such as the polar cap, auroral zone, and the vicinity of the magnetic equator.
 - (d) Those that are remote from other stations, magnetically conjugate to other stations, or in the Southern Hemisphere.
 - (e) Those operated in conjunction with well-instrumented geophysical observatories and special research facilities.
75. When a station is closed, care should be taken to safeguard its data for the use of the international community.
76. Because of the wealth of data that ionosondes provide they should be operated, not in isolation, but in conjunction with other techniques to provide a broad picture of the ionosphere, as an integral part of man's study of the upper atmosphere.

IV. Detection of Magnetospheric Phenomena by Ionograms

The article reproduced below was prepared by W. R. Piggott for the Handbook of the Committee for Coordination of Observations Associated with GEOS (CCOG), particularly to draw attention to the possibility of using ionosondes to detect magnetospheric phenomena using ionograms. It has since been quoted in other contexts, and the INAG Meeting at Seattle suggested that it should be reproduced in the INAG Bulletin. The techniques suggested are even more powerful when applied to the Southern Hemisphere because of the displacement of the Southern Invariant pole from the Southern Geographic pole. The auroral oval and other magnetospheric boundaries move more regularly as the earth rotates in this hemisphere.

IONOSPHERIC SOUNDINGS ASSOCIATED WITH GEOS

By

W. R. Piggott (Ionospheric Consultant to CCOG)

The application of ionosonde data to IMS problems has not been adequately studied and the possibilities are not understood by many potential users. The purpose of this note is to discuss briefly the types of information which can be made available readily and in particular to draw attention to certain applications which are often overlooked. The major limitation in the use of such data is due to the absorption which can be generated by the more penetrating particle activity which prevents the signatures of the phenomenon from being seen on the ionograms. When riometer data are also available the type of absorption phenomena can often be recognized by its variation in time. It appears probable that in these cases the presence of the absorption itself can be used to give limits to the positioning of a boundary.

Both aircraft and ground observations have shown characteristic changes in the ionogram pattern at the auroral oval, at least under average conditions. The usefulness of these criteria during severe magnetic storms is not yet known.

The electron density structures in the ionosphere are very sensitive to coupling between the plasmas of the magnetosphere and ionosphere, to the presence of winds and electric fields, to the composition of the neutral atmosphere, and to the incidence of energetic particles or hot plasmas. Ionospheric scientists are making special efforts to get uniform nomenclature and procedures for studying these phenomena during the I.M.S. Groups primarily interested in solar effects on weather and climate are also becoming interested in the phenomena found in the ionosphere at high latitudes. The 22-year cycle in meteorological parameters found at low geographic latitudes strongly suggests that the changes in the solar wind are responsible. All the apparent solar cycle relations with weather and climate involve major scientific problems for which IMS studies should be critical (ref: Solar Terrestrial Physics and Meteorology - A working document, SCOSTEP, July 1975, compiled by A. H. Shapley, H. W. Kroehl, and J.H. Allen, 142 pages, Acad. Sci., Washington, D.C., U.S.A.).

At high latitudes the ionosonde sees the maximum electron density for E and F layers present within a considerable area, as well as sounding that nearly overhead. It can detect the ionisation structures associated with the auroral oval, with plasma instabilities in the ionosphere, with hot solar plasma, and local particle precipitation as well as showing the indirect effects of the coupling between the magnetosphere and ionosphere. These can be studied at two levels:

- (a) Morphological
- (b) Detailed studies of particular phenomena.

The most important applications of (a) for CCOG purposes are to establish whether and when particular phenomena occur, and thus to monitor important magnetospheric parameters. For this application it is only necessary to know when and for how long, particular types of ionogram are observed at one or more stations. The main interest in (b) in the past has been to find out the maximum electron density and the height at which it is produced by particle activity, as seen by rocket or satellite observations. The accuracy and value of the data can be increased considerably by the use of directional ionosondes or similar techniques.

Monitoring the Auroral Oval

The auroral oval is asymmetric about the geomagnetic pole, typically reaching 10° lower latitude near geomagnetic midnight than near geomagnetic noon and more than doubling in width as it moves to the lower latitudes. Its exact position varies considerably with changes in solar wind and hence with solar and magnetic activity. As the earth rotates, stations at suitable geographic latitudes are carried across the auroral oval (Fig. 1, p. 98) and can detect its presence by characteristic changes in the patterns shown by the ionograms when it passes overhead. Such changes vary with season and day or night conditions, but are believed to be present at all times at which the oval crosses the station. In some cases, of course, high absorption may prevent them from being detected. There is strong indirect evidence that there is always enough activity in the auroral oval to give readily detectable changes on ionograms. Whenever typical oblique traces can be identified and their range measured, the position of the oval can be detected even if it is several hundred kilometers from the station. Normally the equatorial edge shows the most characteristic traces and their positions in latitude can be estimated to better than one degree when the geometry is favorable. Stations on the polar side of the auroral zone are especially valuable for monitoring the position of the auroral oval for most days. The immediate action needed is to complete agreement between different groups operating high latitude stations on the exact criteria to be used and to arrange for interchange of the times when these criteria are present. Data from the local longitude zone are likely to be most readily available, but data from other longitudes can supplement this when local blackout intervenes or when conditions are complicated.

Since most particle activity is centered near magnetic midnight, observations at times well displaced from magnetic midnight are more valuable for evaluating the position of the oval accurately than those taken near magnetic midnight.

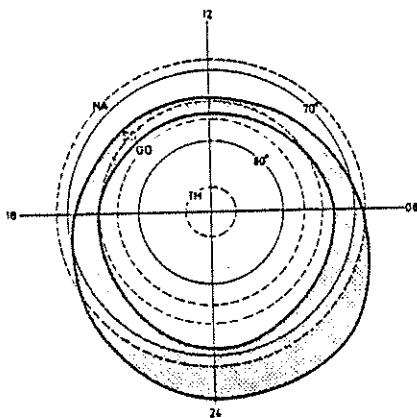


Figure 1. Positions of Søndre Strømfjord Rocket Range (SS) and the geophysical observatories Thule (TH), Godhavn (GO) and Narssarssuaq (NA) with respect to the average position of the auroral oval in corrected magnetic-latitude/magnetic local-time co-ordinates.

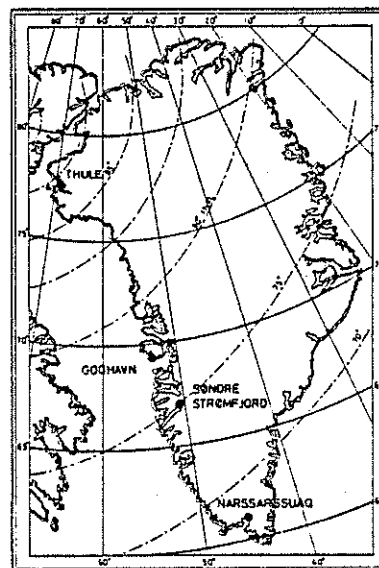


Figure 2. Map of Greenland showing position Søndre Strømfjord Rocket Range and of the geophysical observatories at Thule, Godhavn and Narssarssuaq. Dashed curves indicate corrected geomagnetic latitudes.

Monitoring the Direction of Interplanetary Magnetic Field

There is evidence that the Slant Es condition (SEC) is due to plasma instabilities generated by abnormally great dawn-to-dusk magnetospheric electric fields. The phenomenon is common inside the auroral oval but is believed to occur most frequently under the auroral oval and at the magnetic pole. Near the pole it shows peaks in occurrence in the early morning or late evening, depending on the sense of the interplanetary magnetic field, and this offers the possibility of using this phenomenon to monitor the field from the earth's surface. The possibility of using the phenomena as an index of the intensity of the total dawn-to-dusk electric field does not appear to have been studied.

Incidence of Hot Solar Plasma

Hot solar plasma incident from the polar clefts can cause easily recognised changes in the F2 layer, particularly in the summer months. In general the normal F1 and F2 pattern is replaced by traces from a low F2 layer with abnormally high critical frequency. The changes from normal to abnormal pattern, or vice versa, occur very quickly, in marked contrast to the changes associated with changes in the position of the auroral oval. These patterns have often been detected in the polar cap and on a few occasions on the equatorial side of the auroral oval. They are often superposed on typical auroral oval phenomena near the midday sector of the auroral oval. It is not as yet known whether they can be uniquely identified in the presence of normal auroral oval phenomena using ground-based observations alone. The relatively high temperature of the plasma identifies the phenomena in rocket and satellite observations.

Particle Precipitation

(a) D region

Particles penetrating to the D region (below about 95 km) are readily detected by ionosondes when the precipitation is overhead. The technique is extremely sensitive and total blackout occurs readily. The time variations of the excess absorption are usually more readily studied using the riometer, though ionosonde measurements are always desirable to study weaker events and to show that absorption seen by the riometer is due to F-region phenomena. This is especially important when severe spread F is present since the F region can then give absorptions of 1 or 2 dB at 30 MHz. When PCA phenomena are present the ionosonde is more sensitive to solar electrons than to solar protons, whereas the reverse is true for the riometer. This can be used to give warning of PCA events, since the electrons normally arrive earlier than the protons.

(b) E-Region-thick layer

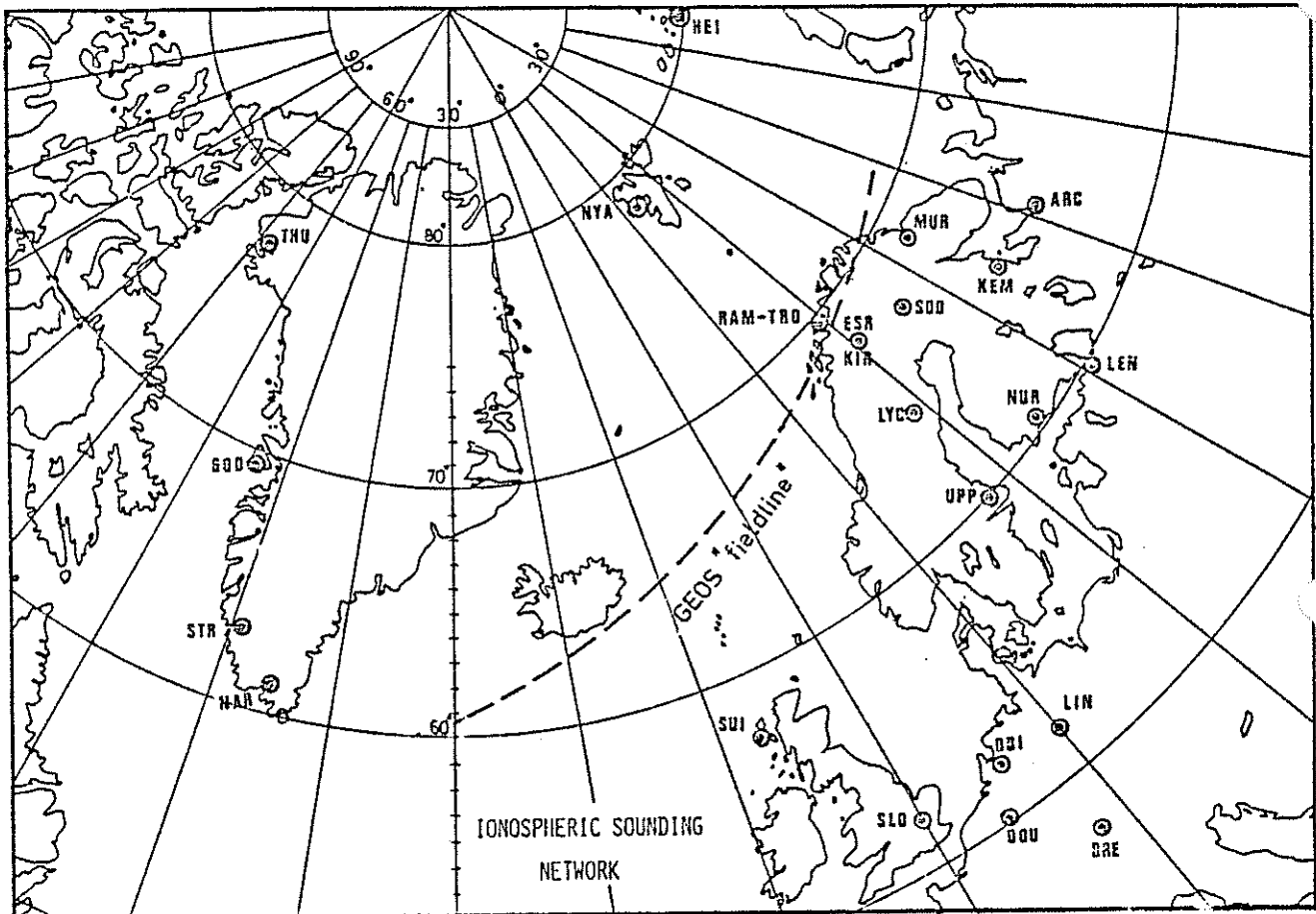
Traces due to thick layers in the E region (Particle E, -Night E) are readily recognised, and their critical frequencies are usually well defined. Two main classes of Particle E are found. The best known is associated with auroral activity and moves more or less in step with changes in the auroral oval. It is usually found some five degrees in latitude displaced towards the equator from the maximum of the visible aurora. The highest electron densities and critical frequencies appear near the lowest latitude affected by the phenomena. In general, as with most particle effects in the ionosphere, the height and maximum density are inversely related; most auroral associated layers appear to be formed below 130 km. The second particle E phenomenon occurs mainly at greater heights, between 150 and 200 km. It shows short time variations similar to those expected from local particle precipitations but is found at times and in places when auroral activity is not evident. It is common at much lower latitudes than the auroral associated Particle E phenomenon.

(c) E-region-Es layer

Provided that the F layer is not too tilted, blanketing of Es gives a direct measure of the effects of particles overhead (fbEs), but the majority of Es traces associated with geomagnetic storm conditions (other than those with foEs close to fbEs), are seen at oblique incidence. The traces can show the maximum density of the Es layer at distances up to several hundred kilometres. The scaling rules are at present under review. It is not clear whether the Es phenomena above the station should be stressed or at the most intense Es phenomena near it. Guidance from potential users is required.

(d) Plasmapause trough

When the F layer is not illuminated by the sun (winter night conditions) a highly characteristic variation of electron density with position is found near the edge of the plasmapause. The critical frequency of the F layer decreases significantly, and its height increases by 100 km. or more to form a trough in the electron density, with width along the magnetic meridian of 100-300 km. A dense, field aligned structure is usually found on the polar side of this trough which is readily detected by the ionosonde. Typical particle-produced Es traces are usually present near the edges of the trough. The position of the polar ridge can be followed with an accuracy to a fraction of a degree in latitude from suitably placed stations, though over Scandinavia the interpretation can be complex, as simultaneous reflections are usually present from several azimuths. Relations between the boundaries of the different auroral phenomena appear to be controversial, possibly because they appear to be close together during major storm conditions but separate in quiet conditions, i.e., when detected at higher latitudes.



(e) Detection of winds and fields

Both winds and electric fields in the ionosphere can move the ionization, particularly in the F region. Winds cause movement along the magnetic fields, electric fields, at right angles to it. Such effects extend well beyond the zones where particle precipitation is taking place and can thus be detected by suitably placed stations, even when stations near the auroral oval are totally blacked out. It is probable that such phenomena are best studied using one or more fixed frequency pulse transmissions, since such changes can occur very rapidly. However, these must be interpreted with the aid of standard ionograms taken preferably not less frequently than at quarter-hourly intervals. Little work of this type has been done since the earliest days of the ionosphere, but it appears to be timely to reconsider the value of this type of investigation.

As mentioned above, the normal dawn-to-dusk electric field in the magnetosphere is close to the critical value at which plasma instability can be generated in the upper part of the E and lower part of the F regions. In summer months local increases in field above the critical value show up on the ionograms as Slant Es and Lacuna patterns.

Note: Dr. W. R. Piggott has written the paper especially for this report to stress the importance of ionosphere soundings at high geomagnetic latitudes. Unfortunately, we have not had success in filling the gaps in the ionosonde-network north of the Scandinavian mainland.

V. Future of Port Stanley

by

W. R. Piggott

The Director of the Appleton Laboratory has drawn my attention to the fact that he is actively considering closing the station at Port Stanley in 1979. Noting that this station meets four of the criteria in Dr. Rishbeth's report for identifying a key station, I feel that the users of Port Stanley data should be requested to state whether they wish the station to continue and for what reasons. Although in the past Port Stanley data have been widely used for research in the U.K., there is now little interest in it outside the British Antarctic Survey, *thus the main justification for maintaining this station must come from international requirements.*

VI. Translations of the High Latitude Supplement

INAG is pleased to announce that two translations of the High Latitude Supplement have been published.

A Spanish translation has been prepared by the Laboratorio Ionosferico Armada Republica Argentina (LIARA) and published as LIARA Document C27, dated February 1977. The translation was made by M. L. de Leon de Giraldez, under the direction of Dr. A. E. Giraldez, and Cdr. A. H. Garbini, Director of LIARA. The project has been sponsored by the Argentine Navy and by the Radio Scientific Committee of Argentina (CORCA) and the National Commission for Solar Terrestrial Studies (CNEGH) as part of the National Program of Radio Propagation Studies.

A Japanese version has been prepared by the Radio Research Laboratories, Ministry of Posts and Telecommunications, in Tokyo, under the direction of Dr. A. Kasuya.

Copies of these translations can be obtained from:

LIARA, Avda. del Libertador 327,
1638 Vicente Lopez (Pcia. B.A.),
Buenos Aires, Argentina

and

Radio Research Laboratories,
Ministry of Posts and Telecommunications,
2-1 Nukui Kitamachi, 4-chome,
Koganei-shi, Tokyo,
184 JAPAN.

Since many of those directly concerned with ionogram interpretation and reduction have difficulty with English texts, translations of these types are very valuable and greatly assist in maintaining both local interest in the subject and in improving the quality of the analysis procedure.

INAG wishes to thank, on your behalf, our Argentinian and Japanese colleagues for the considerable effort they have made in completing these projects, and recommends that these translations be widely circulated to Spanish- and Japanese-speaking ionospheric workers, respectively.

VII. NOAA Cooperating Observatories

NOAA's inventory of ionosondes now comprises 36 instruments: 11 C-2's, 12 C-3's, 11 C-4's, and 2 J-5's. Three of these, at Boulder, Maui and Wallops Island, are operated by the National Geophysics and Solar-Terrestrial Data Center (NGSDC) personnel with support from NOAA's Environmental Research Laboratories and NASA's Wallops Flight Center. The Cooperating Observatory Branch of NGSDC's Solar-Terrestrial Physics Division operates these stations, and is responsible for the deployment and logistic support of the rest of the ionosondes.

Thirty-one ionosondes are on loan to other agencies or governments, and are deployed in a total of 21 countries. Most of these sounders are operated routinely in monitoring programs. A condition of the loans is that the data be made available to the scientific community through the World Data Center system. A few of the sounders have been loaned specifically for "research mode" operation, where they are operated only irregularly in support of special programs such as rocket launches. In these cases also, sharing of the special data is a condition of the equipment loan.

A continuing program of refurbishing, rehabilitating, and to some extent, updating, has been responsible for the long operating life of these aging instruments; the C-2's will be 30 years old next spring. In the last 7 years alone, four C-2's, seven C-3's, and five C-4's have been refurbished and redeployed. The last (a C-4) is now enroute to its new assignment at San Juan, Argentina.

The continued viability of the refurbishing program is contingent on availability of special parts and sub-assemblies. In some cases, particularly for the C-4, the stocks which we have hoarded over the years are now depleted, and no further replacements are available. The cannibalizing of some sounders to sustain others has been used. This is relatively ineffective, since the electromechanical parts all wear out in the same pattern. As a result, we expect in a few years that the old instruments will no longer be capable of productive service. At present it does not appear technically feasible to attempt a piecemeal redesign program to "transistorize" the Model-C ionosondes, one subassembly at a time. Instead, replacement of the Model-C ionosondes with a "new-from-the-ground-up" solid-state monitoring ionosonde, such as that represented by the Australian Model 4-A, would appear to be a good alternative. Eventually the development of the NOAA digital research ionosonde should provide a "spin-off", producing an ionosonde useful for the monitoring networks.

In the meantime, we will continue to strive for the best utilization of our existing instruments. Inquiries and requests for the long- or short-term loan of Model-C ionosondes will be given every consideration, but only a few requests can be met, and a long lead time is to be expected. An under-utilized instrument must be identified and arrangements made for its return to Boulder. Then it must be completely overhauled and tested. This process becomes more difficult to accomplish as the replacement parts problem continues to worsen and concurrently, the number of potentially refurbishable sounders has declined.

Attrition has reduced the NOAA ionosonde inventory by 10 sounders in the last 7 years. In some instances, it was because of cannibalization. In other cases, instruments were judged too decrepit to refurbish and were dropped from NOAA's inventory without being returned to Boulder. Now being replaced is the C-3 destroyed by fire at San Juan, Argentina, in 1974.

Unavailability of replacement parts and limited manpower have made our support of our Model-C ionosondes in the field less than we wish it might have been. We want to thank our cooperators who struggle successfully producing data with these 20- to 30-year-old ionosondes for their persistence and dedication. It is a testimonial to them, as well as to the designers of these durable, and at times, cantankerous contraptions, that the data center archives continue to swell with more and more ionograms for which the demand continues to grow.