Summary of URSI-STP Meeting on the Vertical Soundings Network

Introduction

A special meeting on problems connected with the ionospheric vertical soundings network was held on 30 January, 1969 at the Royal Society, London, during the First General Meeting of the Inter-Union Commission on Solar-Terrestrial Physics. The meeting was called by the URSI-STP Committee, Professor W.J.G. Beynon, Chairman, in consequence of discussions and resolutions of the URSI-STP Committee at its meeting at Brussels, September 1968 (see URSI Information Bulletin No. 169, pp. 48-59, particularly p. 51).

The attendance was: W.J.G. Beynon (UK), Chairman; G.M. Brown (UK), Secretary; W.R. Piggott, J.W. King (UK); J. Turner, Z.R. Jeffrey (Australia); K. Rawer, W. Dieminger, B. Beckmann (GFR); N.V. Pushkov, V. Migulin (USSR); A.H. Shapley, J.W. Wright, K. Bibl, S.A. Bowhill, T.N. Douthit, C.F. Power, N. Brice, H. Carlson (USA); L.E. Petrie (Canada); J.K. Oleson (Denmark); V. Padula-Pintos, O. Schneider (Argentina); G.M. Pillet (France); P. Triska (Czechoslovakia); J. Taubenheim (GDR); C.M. Minnis (URSI). In addition, written comments especially for this meeting were available from: R. Lindquist, W. Stoffregen (Sweden); R.G. Rastogi (India); A.A. Giesecke (Peru); R. Halley (France).

Much preparatory work was done in the days immediately preceding the meeting by a sub-group of IUCSTP Working Group 1 on Monitoring of Solar-Terrestrial Phenomena. This sub-group under W.R. Piggott held five half-day meetings with varying participation but including about half the above names. It discussed general problems as well as many matters of detail which could not be treated at the meeting. The meeting used the work and conclusions of the IUCSTP WG1 sub-group as the point of departure.

This report covers the general results of the meeting and the recommendations which represent the consensus of the discussions. The more detailed points covered in the preliminary meetings are treated in Appendix 1, under the responsibility of the URSI-STP Vertical Soundings Consultant, W.R. Piggott, and IUCSTP Working Group 1.

Discussion

Professor Beynon summarized the objective of the meeting as given by the URSI-STP Committee's Brussels meeting: "...a meeting of those responsible for the operation of vertical sounding stations to discuss

the whole problem of an optimum network, morale and general maintenance of standards at the stations. The distribution of stations would have to be examined in relation to the IUCSTP programmes." He referred to the preparatory document prepared by the Vertical Soundings Consultant, W.R. Piggott, which had received wide circulation and had been available in advance of the meeting (Appendix 2).

Mr. Piggott summarized the conclusions of the preceding sub-group meetings, which discussed the question of the size of the network in great detail. The consensus was that a network of roughly the present size will be required at least for the period of the IASY and that stations already operating ought to be maintained for this period. This was consistent with the views collected in Appendix 2. The sub-group remarked on several kinds of emphasis which ought to be placed at various kinds of stations. However the performance of the network ought to be improved by internationally stimulated actions such as visits by experts, by "feed-back" to stations on research and other use of their data, or by other encouragement and guidance. He observed that there was an anomaly in that the use of vertical soundings data had steeply increased in the last few years while the size of the networks and overall quality had decreased. The sub-group recommended that URSI should not make negative recommendations but rather take a series of constructive yet realistic steps.

Professor Bowhill reported on a poll taken in his IUCSTP Working Group 11 of scientists who actively use ionograms on the level of vertical soundings activity which is desirable within the scope of his Working Group, Ion Chemistry of D and E Layers:

(a) three votes for maintenance at least at present level;

(b) no votes for a not more then 10% reduced level;

(c) six votes for a 30-40 "key" station network with carefully chosen locations and upgraded capabilities.

Dr. King said the consensus in his IUCSTP Working Group 12, Sudden Ionospheric Disturbances, was that the network size was satisfactory as long as particular attention was paid to rocket-launching sites. He saw no real problem except that the quality must be improved.

It was reported that IUCSTP Working Group 5, Conjugate Point Experiments, had adopted a resolution both endorsing the need for vertical soundings at conjugate pairs of stations and for the network as a whole to deal with problems of non-conjugacy.

Professor Rawer pointed out that the network was becoming more important as a support to other ground-based and space work compared to its earlier role in "primary science." Professor Bowhill called attention to URSI-STP Resolution 5 (Brussels 1965 and Appendix 2), which inter alia

recommended the need for the network to be flexible to meet changing needs. Professor Dieminger and others stressed the need for more high-accuracy stations, and Dr. Bibl felt that the present number of stations should be maintained. Professor Rawer described a hypothetical realistically-distributed 30-station network and said geophysical studies would not be satisfied with such a network. Mr. Wright pointed out that most stations (e.g., 29 of the 37 more or less associated with USA) would likely continue for local or other reasons even if the justification of being part of a network were withdrawn. Mr. Petrie and Mr. Shapley said international recommendations would have some weight in local decisions about the conduct of vertical soundings work. However, Mr. Petrie said three of the five Canadian stations are justified by support to other work -- rocket experiments and partial reflection observing programmes, and enquired, "What are the STP requirements?" The Chairman said this was the central question, which has not yet had a clear answer. Dr. Bibl pointed out some probably major gaps in our description or understanding of the ionosphere which still remain and which vertical soundings can assist. Dr. Pushkov said our objective should be to get existing stations to work properly for IASY. Professor Rawer stressed the need to modernize the old-fashioned methods of data handling currently in use.

The Chairman said there was a clear consensus of this quite broadly representative meeting:

(a) The existing network ought to be maintained at about its present size, but that steps should be taken for improvement of performance; chief among these are visits by experts to stations, and an even more active URSI mechanism for guidance to stations, including the provision of comments, on request, regarding planned opening or closing of stations.

(b) Some stations should be strongly encouraged to obtain highly accurate vertical soundings data, in particular stations which are in support of rocket work or Thomson scatter installations, or which are at large and complex research institutions.

(c) Synoptic stations should be strongly encouraged to obtain as complete numerical data as possible; to this end, URSI-STP will re-examine the present "accuracy" rules in order to maximize the amount of numerical data available for synoptic purposes.

(d) Vertical soundings measurements are not being used to their full potential for network purposes for study of ionospheric absorption; URSI-STP should prepare some detailed recommendations.

(e) Improvements should be made in the handling of vertical soundings data in computer-compatible form. Again recommendations and action are needed by URSI-STP or by IUCSTP WG1 and the WDCs.

(f) Design and plans should begin to be developed for the vertical soundings network of the mid 1970s.

(g) The detailed recommendations and proposals of the sub-group as given in Appendix 1 should be supported.

Appendix 1. Summary Conclusions and Detailed Recommendations of Ionosonde Network Sub-group of IUCSTP

Appendix 2. "Future of Vertical Incidence Soundings Network," report compiled by Vertical Soundings Consultant, January 15, 1969

Appendix 3. Circular and documents 1-4 issued by Vertical Soundings Consultant

Appendix 4. Collected Comments on Vertical Incidence Soundings Network

Appendix 1

Summary Conclusions and Recommendations of IUCSTP Ionosonde Network Sub-group

The following are summary conclusions resulting from extensive and detailed discussions held January 28-30 at London in an ad hoc sub-group of IUCSTP Working Group 1, Chairman W.R. Piggott. The participants included many of those who participated in the URSI-STP sponsored meeting on the same subject on January 30, and the work of the sub-group was intended and is considered to be preparatory to that meeting. The remarks and conclusions of the circulated report (Appendix 2) were accepted as representative and most of the discussions were aimed at finding ways of meeting the disclosed difficulties.

1. Vertical Soundings Network Recommendations and Conclusions

The Working Group noted and supported the recommendations numbers 3, 4, 5, 7, 8, and with modification 6, of the URSI-STP Committee made at Brussels September 1968, which are published in the URSI Information Bulletin No. 169, December 1968, pp. 48-59, and reproduced in Appendix 2, section 6. The recommendations below supplement these.

Rec. 1 Size of Network

The Working Group noted the views of consultants summarized in the circulated document, considered the use being made at present of data from high, low, and temperate latitude stations, felt that this use fully justifies the maintenance of the existing network at least for the period of the IASY and strongly recommends that stations already operating be maintained for this period.

Rec. 2 Redeployment

The Working Group considers that the scientific value of proposals to alter the deployment of stations should be balanced against the cost and recommends the setting up of a small ad hoc group of experts, with knowledge of conditions in widely separated parts of the world, for the following purposes:

(a) to examine methods of determining where stations should be maintained or set up.

(b) on request, to consider and examine proposals for redeployment, closing or opening of stations, so that the organizations involved can be given a balanced brief for such proposals.

(c) to consider methods whereby the data required in the future could be more economically obtained paying special attention to the different logistic and technical needs in advanced and developing countries.

(d) to report to the URSI-STP Committee within two years.

The WG notes that certain weather ships and meteorological stations exist at sites which would be very valuable for obtaining ionospheric data for scientific and operational purposes, and further recommends that the possibility of planning ionosondes or other ground-based monitoring instruments at these stations be investigated by the administrations involved.

Rec. 3 High Accuracy Stations

The Working Group draws attention to the need for data with a higher accuracy than is usually obtained at rocket ranges, near Thomson scatter stations and where intensive studies of solar-terrestrial, ionospheric or magnetic problems are active; noted that some investigations using ionosondes demand an accuracy which is only available at one or two stations (e.g., Lindau); and draws attention to the need for a few more stations with this accuracy.

The Working Group recommends that action be taken to fill these needs.

The Working Group also stresses the need for synoptic data from these stations, and recommends that such stations be operated regularly and the data obtained circulated even if it is not needed by the particular experimenters involved. In particular, groups using published data on rocket or satellite observations often need to know the synoptic conditions when the observations were made.

Rec. 4 Information Bulletin

The Working Group felt a need to improve communication between the stations, the scientists using the data, the International Unions involved, e.g., URSI, IAGA, IUCSTP, and recommends the regular circulation of an Information Bulletin addressed to the stations of the network and all others concerned. The Bulletin should include all International Recommendations involving its recipients, notices of Retrospective World Intervals and other special study periods, information on outstanding Solar-Terrestrial phenomena, discussions on scaling or other problems at stations, suggestions for Regional studies, and notes on new projects or techniques, particularly when they involve interdiscipline cooperation. There should be a section where inexperienced workers could raise their difficulties and request advice. A particular need at present was to interchange information on shipboard and aircraft techniques.

Rec. 5 Visiting Experts

The WG considers that the most urgent STP requirement is to improve the operation at stations in the existing network which apart from other important uses is valuable for STP monitoring, and recommends:

(a) That suitable experts be sent to visit the stations, particularly in the developing countries, to give advice on the analysis of ionograms, instrumental problems and to improve morale by drawing attention to the current intensive use of the data produced particularly in support of other projects, often in other disciplines. Initially special efforts should be made to visit the South American and African stations.

(b) That international interchange of station staff be encouraged.

(c) That young graduates be encouraged to spend a year or more as operators at V.I. stations both to help the station and to obtain first-hand knowledge of the characteristics of the ionosphere in different parts of the world.

Rec. 6 Synoptic Stations, Revised Rules

The Working Group recognizes that current scientific needs demand both high accuracy data and data which is as complete as possible, particularly for monitoring events, comparisons with satellite data and synoptic problems. These are not necessarily in competition; high quality equipment, well monitored and maintained, can do both in many areas. In general, completeness of numerical data can only be obtained by accepting lower accuracy when the ionospheric conditions are difficult.

The Working Group therefore recommends that the accuracy rules for synoptic stations be revised and requests the V.I. Consultant to do this and circulate the proposals in time for confirmation at the next URSI General Assembly and CCIR Study Group VI meeting.

2. Interchange of Data by Computer Techniques

The Working Group strongly believes that in the future most numerical data from the V.I. network should be handled, interchanged and stored in forms usable by computers, draws attention to the growing use of computers for handling synoptic data and the need to produce data in forms readily compatible with each other. This involves:

(a) use of a single system of station identification (Brussels, Rec. 8)

(b) setting up arrangements so that data processed locally by incompatible computers can be economically converted to an international standard form.

Rec. 7 Characteristic Codes

The Working Group notes that the characteristic codes for punched cards given in the Handbook (Piggott and Rawer) have been generally accepted for both card and tape use and recommends that these codes with additions agreed upon at the London meeting 1969, as listed in the table on page 15, be adopted internationally.

The Working Group recommends that the following characteristic codes are also added to the existing list, to be used for interchange on a voluntary basis:

02 fzF2
07 MUF(3000)F2 (change of code number)
17 MUF(3000)F1 (change of code number)
26 h'E2
44 h'F1.5
47 fm2 (minimum frequency of second order trace)
48 fm3 (minimum frequency of third order trace)
together with codes given in Rec. 13 below
57 dfS (frequency spread of spread F reflections)

Notes on Characteristic Codes

Card column 12 (Layer identification), index 5 was originally reserved for solar indices (Handbook) but has not been used for this purpose. These use an independent code system. It is therefore adopted for parameters associated with spread F and oblique reflections, see URSI-STP Rec. 6 and Rec. 12, below.

The table includes both international characteristics and certain others which are regularly analyzed at some stations and are interchanged on a voluntary basis. In some cases a code has been adopted arbitrarily but in general the WWSC system has been adhered to.

The following parameter has not been defined internationally before:

06 h'Ox height of extraordinary wave trace at frequency equal to foF2

Parameters 47, 48, 50, 51, 52, 53, 54, 57 are defined in Recs. 12, 14 below.

Rec. 8 Standards for Tape Interchange

The Working Group notes that interchange and storage in punched card form is inconvenient and expensive but that there are often serious difficulties in reading punched or magnetic tape in different countries and in different institutions in the same country due to incompatibility between computers and computer languages.

The Working Group recommends that the standard parameters recognized for international interchange and listed in the characteristic codes (as amended) be stored at each WDC in such a manner that the equivalent punched cards can be readily produced without the use of specialized and large computers. The actual types of tape and language used should be determined by local conditions and the needs of the users of the data from that WDC, noting that the needs of groups with small computers or card handling facilities should not be overlooked.

The Working Group recommends the setting up of a small working party of experts linked with WDCs who have experience in the different types of computer and computer language with preferably an independent chairman to examine the problem of computer incompatibility and to make recommendations on the most efficient ways of overcoming these difficulties, e.g., by the centralization of conversion programmes or provision of data in different formats.

Rec. 9 Interchange of Computer Processed Data

The Working Group recommends that circulation of numerical data in a standard form (punched cards or an acceptable computer tape) be recognized as equivalent to sending data in tabular form for the purposes of international interchange through the WDC system.

Rec. 10 Centralized Processing of Data

The Working Group feels that centralization of some steps in the handling of data from stations is rapidly becoming essential since all the data will be needed in computer compatible form and it is inefficient and inaccurate to process data by hand when it will eventually be computerized. The Working Group recommends that all organizations having access to computer processing should use it both for interchange and, where desired, for the production of tables.

The Working Group draws the attention of the administrations responsible for WDCs and large station administrations to the advantages of storing, interchanging and handling numerical data by machine and the need to agree to a mechanism whereby data from stations without suitable facilities could be converted to standard forms. The Working Group suggests that the possibility of centralized punching of such data be considered and points out that costs at the station could be reduced if the data were sorted by computer and the standard tables printed out centrally and sent to the station. Work at these stations would then be restricted to preparation of standard daily work sheets only and sending these to an agreed center would meet the international interchange agreements. The Working Group suggests that a suitable body (e.g., IUCSTP WDCs Committee) examine requests for central computing from time to time and limit those accepted to cases of need.

Rec. 11 Standards for Sophisticated Equipment

The Working Group notes that sophisticated methods of producing ionogram data in numerical form are being developed in several groups, that there is a need for a standard format so that the data produced can be readily interchanged internationally and recommends that those working in this field keep in close contact with each other (see URSI Bulletin No. 169, December 1968, pp. 32-40).

The Working Group notes that the operation of ionosondes on ships and aircraft involve specialized engineering and data handling problems but are very important and recommends that their use be strongly encouraged.

3. Changes in Parameters

Rec. 12 Revised Recommendations for Spread F Parameter

The Working Group endorses the proposal to establish a new international index for spread F (URSI Bulletin No. 169, December 1968, URSI-STP Rec. 6, p. 56) and discussed details of rules for this index and for the interchange of related parameters which may be circulated in the future. It was concluded that some confusion of the originally suggested nomenclature with the satellite parameter fxS (extraordinary mode plasma frequency at the satellite) was likely and that the nomenclature should be changed to avoid this.

The Working Group recommends the following changes and additions to URSI-STP Rec. 6:

(a) Codes

Computer Code	
50	Reserved for foI if required
51	fxI, (previous nomenclature fxS, 41)
52	fmI, lowest frequency of spread (in use at some stations only)
53	M(3000)I, factor deduced from spread (in use at some stations on experimental basis only)
54	h'I, minimum slant range of spread (in use at some stations only)

Only fxI is recommended for general use at present but data available for the other parameters in punched form should conform to the recommended code.

(b) Missing values of fxI. The WG recommends that, for hours when spread F is usually present, the value of fxF2 with descriptive letter X be included when spread is absent so that the count and median can be representative of communication conditions for the month as a whole.

(c) Treatment of slant F. Pending further investigation, the WG suggests that slant F be treated like a polar spur for obtaining the value of fxI.

(d) Frequency spread dfS. For scientific work, where the spread of the conventional scatter pattern is most important, the WG draws attention to the use of frequency spread at a number of stations and proposes that this be a recognized international parameter for interchange on a voluntary basis. The code 57 and symbol dfS is suggested for this and comments are invited from all concerned in time for acceptance, modification or rejection at the URSI General Assembly August 1969.

Rec. 14 Change in Data Exchange Rules

The Working Group stresses that f-plots or equivalent records are essential for both accuracy in analysis and understanding of high latitude V.I. data and for intensive studies of the ionosphere elsewhere.

It therefore recommends:

(a) That all stations take ionograms at least at quarter hourly intervals.

(b) That current practice be maintained at high latitude stations but elsewhere f-plots be prepared only for selected Retrospective World Intervals, chosen primarily to support the special projects of the STP.

(c) That the declaration of such intervals be entrusted to the existing RWI mechanism, supported by the advice of the Chairman of the STP working groups where appropriate. The need for quick decision and circulation of these intervals is stressed.

Rec. 15 Monitoring of Absorption by Ionosondes

The Working Group notes that the variation of absorption with position and time appears to be more complicated than can be adequately monitored by existing absorption stations and recommends that all V.I. stations attempt to produce a parameter which is dependent on the absorption present.

The following techniques can be used to obtain an improved measure of absorption for synoptic purposes and the Working Group recommends that they be adopted, as appropriate.

(a) At stations where fmin is mainly determined by absorption, at least when it is appreciable, the operation of the ionosonde should be examined and changed where needed to make the fmin values more consistent. In particular in any month diurnal gain changes should be made at fixed times of day only and the gain at fixed time be kept as constant as possible. Where possible the times and gain changes in dB should be recorded and circulated with the fmin data.

At stations where the fmin for the second order trace, fm2, is mainly determined by absorption, measurements of fm2 will usually show absorption changes more accurately than fmin and be less sensitive to interference and equipment characteristics. The Working Group encourages stations to compare fmin and fm2 (or fm3 if usually available) and to report their findings either in the literature or through the V.I. or Absorption consultants.

(b) At high sensitivity stations where fmin is not usually a measure of absorption, the Working Group recommends that fm2 be reduced and circulated instead of or in addition to fmin. Note in this case the appropriate value of fmin should always be shown in tables of other parameters when the parameter is below fmin, e.g.,...EB; ...ES cases. The Working Group encourages the substitution of fm2 for fmin at stations in group (a) when local experience shows that this gives a better description of absorption changes.

(c) The Working Group draws attention to the use of amplitude measures on selected ionograms (e.g., hourly) and of simple attachments to ionosondes which enable crude measure of amplitude to be monitored (e.g., 1967 Rawer & Suchy, Handbuch der Physik XLIXL/2 pp. 248-250; 1964 Paul, A.K.,Electron Density Distributions in the Ionosphere, ed., Thrane E North Holland, pp. 17-20). All such methods can be misleading in particular circumstances which often depend on local conditions -- as can fmin or fm2.

4. Miscellaneous Points

The Working Group draws the attention of IUCSTP and URSI-STP to the generally agreed need for a permanent service for the V.I. network and suggests that the possible alternative ways of meeting this need (S.T.S., WMO type organization, etc.) be examined by a competent body.

The Working Group considered the problems of certain stations whose data were needed for scientific purposes outside the nation concerned. The value of the data from some of these stations could be greatly increased by quite a small subsidy. The Working Group draws the attention of administrations cooperating with such stations to this point and feels that the international needs may justify special support from an international fund. Any application for such support should be firmly established scientifically and be reviewed by a competent body.

The Working Group draws attention to the need to improve the sharing of topside sounder data and to publicize the available facilities, both in tape and booklet form.

The Working Group supported in principle the recommendations of the CCIR and V.I. Consultant for the maintenance of stations for monitoring indices, e.g., IF2, and made recommendations which will be included in the Report to URSI on these problems.

The WG draws attention to the need for more interchange of technical and engineering experience between groups wishing to work on new types of equipment or with ionosondes in ships or aircraft and requests those willing to collaborate to send their names, addresses and speciality to the V.I. Consultant, Radio and Space Research Station, Ditton Park, Slough, Bucks., England, who will arrange for their publication.

The Working Group considered the value of continuing to interchange types of Es but was hampered by lack of representative opinion. The consensus was that Es types were still of value at high and possibly at low latitude stations, but that their main use at temperate latitudes was adequately met by existing data. If this is accepted, the interchange of Es types could be discontinued at temperate latitudes and perhaps at low latitudes. The value of Esq and Es at the latter was stressed. Most current Es studies were local and involved more complex analysis.

The Working Group notes that direct radio scatter from ocean waves is easily observable by efficient shipboard ionosondes, that such recordings can give information on the amplitude and wavelength of ocean waves out to 500 km from the ship and should be of value to oceanographic agencies.

The following recommendations involving V.I. soundings networks were made by IUCSTP working groups at London:

2. Recognizing that comprehensive studies of the conjugate behavior of the ionosphere require continuous records from an extensive network of ground stations, Working Group 5 urges that operation of the worldwide ionosonde station network be continued, and that existing gaps in conjugate coverage be remedied, whenever possible, with the establishment of new, conveniently located stations.

4. Considering the suitable location in L-value and longitude range of the pair of stations at Kerguelan Island (France, South Indian Ocean) and Sogra (USSR), Working Group 5 encourages the pertinent French and Soviet institutions to continue conjugate point studies at these locations, and to implement them with VLF experiments and correlation studies with data obtained from satellites crossing the Sogra-Kerguelen magnetic meridian.

6. Considering the geophysical observations currently being made at Petropavlovsk on Kamchatka (USSR), and recognizing that Canberra (Australia) is almost exactly conjugate to Petropavlovsk, Working Group 5 draws the attention of Australian and Soviet scientists to the opportunity to organize conjugate point experiments at the above pair of stations.

8. Considering the importance of conjugate point studies at low latitudes, Working Group 5 recommends the installation of stations in the region between the Japan-Australia Chain, in which the Ogasawara (Bonin) Islands are situated.

9. Considering (1) that Arecibo Ionospheric Observatory (Puerto Rico) has a conjugate point near an easily accessible area in Argentina, (2) that said Observatory is appropriately equipped to study a maximum number of parameters relevant to conjugate photoelectron effects, and (3) that the field geometry is particularly well oriented for studies of winter-summer comparison, Working Group 5 recommends that a station, equipped with a photometer and eventually an ionosounder, be set up as close as possible to the theoretical Conjugate Point of Arecibo.

Working Group 11 recommends:

2.1 Ionosondes with enhanced antenna efficiency and frequency range extended downward as well as multilink LF pulse and CW sounding should be used for monitoring the night-time E layer ionization (STP 27(68) Sect 1).

CHARACTERISTIC CODES — REVISED

USED FOR IONOSPHERIC MEASUREMENTS — JAN. 1969

		FREQUENCIES			PARAMETERS	HEIGHTS					
CARD COL 13		0	1	2	3	4	5	6	7	8	9
CARD COL 12											
LAYER	0	00	01	02	03	04	05	06	07	08	09
F2		foF2	fxF2	fzF2	M(3000)F2	h'F2	hpF2	h'Ox	MUF(3000)F2	hc	qc
F1	1	10	11		13	14		16	17		
		foF1	fxF1		M(3000)F1	h'F1		h'F	MUF(3000)F1		
E	2	20		22		24		26			
		foE		foE2		h'E		h'E2			
Es	3	30	31	32	33	34		36			
		foEs	fxEs	fbEs	fEs	h'Es		Type Es			
Other	4	40		42	43	44			47	48	
		foF1.5		f min	M(3000)F1.5	h'F1.5			fm2	fm3	
Spread F and Obliques	5	50	51	52	53	54			57		
		foI	fxI	fmI	M(3000)I	h'I			dfS		

Appendix 2

Future of Vertical Incidence Soundings Network

Report of U.R.S.I. Working Group on Ionospheric Soundings to URSI/STP Committee, London, January 15, 1969

Compiled by the Vertical Incidence Committee URSI/STP Committee

Contents

Report of URSI Working Group on Ionospheric Soundings

London 1969

1. Introduction

The Working Group set up by authority of URSI Commission III recommendation III.5 passed at the XVth General Assembly of URSI at Munich 1966, with the terms of reference given on URSI Information Bulletin No. 159, 1966, p. 10, 24-25, prepared and circulated widely the documents reproduced with amendments in Appendix 3 and received many written comments from individuals or groups, Appendix 4. In addition, a large number of specialists commented verbally at international meetings.

The work of the group falls into three sections:

(a) Collecting and summarizing the views of those concerned with ionospheric measurements of a synoptic type.

(b) Preparing the URSI response to certain CCIR questions. This has since appeared in the URSI Information Bulletin No. 167, 1968, pp. 64-84, 'The acquisition of ionospheric data for predictions.'

(c) Reporting to URSI on future needs particularly on the field of measurements.

There were three main types of response to the inquiries made by the Working Group:

(a) Those engaged in producing or using synoptic data mostly felt that the need was self-evident but that the scientific value could be greatly increased by modifications in the deployment and operation of the network ('If we did not think it worthwhile we would not do it').

(b) Most of those not engaged were unwilling to comment in detail ('These documents appear sensible and adequate but we have not the means of testing them').

(c) The remainder felt that all long established programs should be reconsidered and justified in some detail, particularly where the people using the data were not the same as those producing it, taking into account the trends of modern science, new techniques, the probability of worthwhile information being obtained and whether the effort could be diverted to other ends.

We feel that a review of the situation is needed from which future policy could stem, and attempt to meet this need.

The critical comments can be summarized as follows:

(a) The basic rationale for determining the number of stations needed is missing, without this the number and location cannot be determined logically.

(b) Some tough rethinking and rephasing of their problems is needed both by scientists and engineers. Perhaps a smaller number of well-run stations with clear objectives would produce more useful results than a larger network not so well-run. Perhaps new techniques should be employed.

(c) In the final issue action depends on local scientists and administrators whose main interest and concern will be with local problems. They should only be subject to international recommendations which have been thoroughly thought out and are widely accepted as reasonable. Alternatively the case for action should be presented at least in outline so that the relative priorities of local and international objectives can be assessed.

The main part of this report is concerned directly or indirectly, with points (a) and (b). We concur with (c) and have attempted to test proposals put to us accordingly. We feel that other bodies concerned with this type of problem should also look closely at the standards they require before making international recommendations, as there are widespread views that these standards are often too low.

We are very doubtful whether accepted hypotheses about the reasons for ionospheric behavior are adequate or complete, note that the subject is at present growing rapidly and suggest that it is wisest to take a short view and recommend that it is reconsidered in a few years' time. We feel, therefore, that it is necessary to support current research and to give some priority to maintaining the chains of stations around which it is organized.

We stress the change in emphasis of the use of routine data for scientific purposes from the establishment of meaningful average behavior to detailed studies of particular events. This demands much more complete data than have usually been available in the past. Lack of data from particular stations in a chain can easily prevent worthwhile conclusions from being established. Similarly the intensive study of satellite data involves ground-based data being available without too great delay, preferably in a form readily usable by computers.

In our experience the priority ascribed to different possible programs depends mainly on the interests and training of those consulted. Thus those concerned primarily with problems of practical communications stress the need for regular, complete observations and gap filling, but are usually reasonably content with current standards of accuracy. The workers in synoptic solar-terrestrial relations and morphological problems have similar

interests. In contrast most research scientists prefer to plan their own work using ad hoc methods and are most interested in highly accurate and sophisticated methods.

Most classical trained scientists feel that the forces acting, and parameters needed should be determinable by very accurate and intensive observations at a few locations and that there is little object in amassing lower grade observations. In contrast most synoptic scientists are mainly concerned with the variability of ionospheric phenomena as a function of space and time, could be satisfied with lower accuracy when this makes the data more complete or easier to handle and have reservations about whether the intensive approach can be successful, at least for the solution of practical problems.

A balance is needed but there appears to be no common set of values by which the amount of effort appropriate to each group can be estimated. We feel that both groups have a good case but that it would probably be disastrous to the future of the subject if either were given a monopoly; they often do not understand each other but are complementary rather than in competition.

2. Historical

Historically the majority of synoptic soundings stations were set up:

(a) to monitor the ionosphere for operational and synoptic purposes.

(b) to provide synoptic data to control ad hoc scientific investigations.

(c) to create a body of experts on ionospheric problems to whom local operational problems could be referred.

(d) to provide a means of engaging in international research and cooperation.

Planning for the IGY and IQSY was based on the idea that it was desirable to study the latitude variations of the ionosphere in some detail using several North-South chains of stations. The chains were cross-linked, where logistics allowed, by isolated stations or groups of stations, usually primarily set up for getting data for prediction work. Most of the ionosphere has never been sounded by a station within 1000 km and we have, at present little evidence to show whether behavior is similar to that found in the zones of intensive study. In general correlations of day to day behavior get small by about 2000 km spacing and it is likely that medium scale variations with longitude are seriously underestimated.

The big efforts made in the IGY to obtain sensible chains of stations has resulted in the establishment of vertical sounding (V.I.) stations at most sites where this is logistically feasible. Thus, though the deployment

is notoriously inefficient and inadequate, the chance of changing it significantly is small and will demand considerable resources. Much thought has been given to the deployment of station chains which is, therefore, probably already fairly close to an optimum determined by logistical limitations. Most other stations are required for local reasons rather than international (this includes local needs to be associated with international bodies such as URSI or CCIR), or are clearly important for current research.

Resources for running the network which can be redeployed according to scientific needs do not exist except in a very few cases. For example, some stations operate primarily for non scientific reasons. If they are closed we lose the data but do not set free funds and people for use elsewhere. This conclusion applies for many other stations, too. Similarly, we can seldom swop three bad stations for one good one, we can ask for extra facilities for putting a bad one in an important place right but the funds and facilities will seldom if ever come from other parts of the network.

After the IGY, many scientists felt that the network should be reduced from the IGY level of 167 stations to well below the pre-IGY level of 99 stations (1956). In fact it fell to a minimum of 133 active stations in 1962-64 and increased to at least 150 stations in the IQSY. It is now (1969) about 110 stations. After some experimenting with reduced programmes, data analysis and publications after the IGC, most stations have reverted to programmes close to those done in the IGY and have published at least hourly data.

The high level of activity appears to be mainly due to the following factors:

(a) A detailed knowledge of the behaviour of the bottom side of the ionosphere is, in practice, essential for the understanding of the physics of the ionosphere.

(b) Vertical incidence sounding is the cheapest and most efficient method of obtaining detailed information about the ionosphere both for local and synoptic purposes up to the height of maximum of the F2 layer.

(c) The need for current V.I. synoptic data to interpret the results of expensive space projects.

(d) The great increase in the number of workers studying the V.I. data, both for itself and in conjunction with space projects, has increased the demand for more data and has stimulated interest in obtaining it.

(e) The pressure from these workers for additional stations, in order to assist the study of particular scientific or operational problems, has increased the network.

The proportion of data actively studied at most stations has decreased with time and a gap has opened between those acquiring the data and those using it. There is regrettably little feedback to the originating stations, most morphological and prediction work for example is concentrated in or near the World Data Centres and uses data from these Centres. Thus, particularly in some developing countries and at many long established stations, the routine observations give little local prestige and morale and accuracy tends to fall with time. There is a significant number of stations whose data is so unreliable and incomplete that they are almost valueless, and often misleading to those without considerable experience.

3. Objectives of a Synoptic Network of Stations

It is difficult to plan a synoptic system logically because the forces which determine ionospheric behaviour are still only partially understood and therefore the optimum deployment is unknown. Satellite observations will probably clarify this problem within the next few years. We therefore attempt a synthesis of the views of our consultants, CCIR and our own views, reproducing the written comments in Annex 1.

3.1. Long Term Synoptic Problems

There is general agreement that the relations between ionospheric and solar parameters have shown long period changes during the last 35 years and are likely to show further changes in the future. There is need for probably between 10 and 15 permanent monitoring stations, preferably based on those which have already been established for many years, to control this problem. It is also likely that the positions of the auroral zones and the associated particle precipitation zones is changing slowly with time. This needs a few additional stations at critical locations around these zones; possibly eight would be adequate for both hemispheres if suitable sites were available.

It is not known whether similar changes in position occur for other ionospheric zones, e.g., for the equatorial anomaly, prudence would suggest that these should be monitored at least where such changes could cause serious errors in HF prediction.

In general this type of monitoring could be carried out with standard ionosondes conforming to international accuracy rules (Piggott and Rawer, URSI Handbook of Ionogram Interpretation and Reduction, Elsevier 1961) though better height accuracy would be valuable at a few stations to allow long period analyses of tidal phenomena, particularly in the E region.

It appears probable that the CCIR will require an ionospheric index based on observations at not less than 10 well spaced observatories. Economy of effort would suggest a network similar to that used for IF2 but higher accuracy could be obtained using more stations. We are doubtful whether the call for many more stations is economically justified

and feel that, with a few additions to improve the spread of the stations, the present index network is adequate and should be maintained.

The prediction system needs the maintenance of stations monitoring conditions over a wide range of latitude, longitude and dip. The existing network is inadequate owing to large gaps, which are considered below. In our view, the zones at present monitored could possibly be adequately covered in the future by a smaller number of stations, possibly between 30 and 60.

3.2. Control of Ad Hoc Experiments

The main problem in the use of old data is that the ionosphere varies very greatly from occasion to occasion; e.g., for the world as a whole, ionospheric conditions on two quiet or two disturbed days may differ from each other by more than the difference for an average quiet and an average disturbed day. Thus there is a continuing need for synoptic data to compare with the results both of new techniques and of ad hoc experiments.

In general the data are required primarily at or near rocket ranges, incoherent scatter stations and other places where intensive scientific work is progressing. To take full advantage of the data, the equipments should be designed for the highest possible accuracy.

The provision of ground-based data for satellite investigations is more difficult since ionospheric phenomena vary rapidly in longitude as well as latitude. Some current experiments show that a network of 100 well spaced stations is near the minimum needed, in many cases it is too small even to delineate phenomena which are slowly varying with position.

At present a polar orbiting satellite can only be expected to be within 1^{o} of a ground station while the L.M.T of equatorial crossing is within $\pm$ 0.5 hours of a specified time for 20 stations scattered over all latitudes and longitudes, making satellite-ground comparisons difficult and laborious. In practice the position is much worse as so many observations are missing.

3.3. Apparent Network Requirements

The consensus of opinion of our consultants is fairly consistent and amounts to stating that the VI network should be maintained at approximately its present size, but with some revision of deployment, and that the absorption and drift networks should be expanded in the future.

The main departures from these estimates come from groups who have made a detailed study of their needs and, by implication, from the remarks of those with strong regional interests. Thus both Arctic and Antarctic workers point out that their chains of stations are inadequate for many problems and want temperate and low latitude stations moved to these

zones; low latitude workers feel the same and want higher latitude stations moved to the equatorial anomaly zones. To meet both requirements simultaneously without the closing of existing stations would probably involve a network of about 220 stations, i.e., about twice as many as available at present. This figure is also quoted by one group of consultants presumably through a similar calculation.

3.4. Gap Filling

The main CCIR and prediction interest is in gap filling. Experience shows that this is effective in correcting predictions whereas the more advanced analyses can seldom be applied to practical problems. In our view this is a real need but should not, in general, be satisfied by setting up conventional stations since the logistic difficulties are too great. We feel that special equipment should be developed and data from satellites, aircraft and ships be studied to show where these should be deployed. In general we feel that gap filling by conventional means should be encouraged where there is local interest in setting up the stations and analysing the data but that the initiative should come from a local specialised group willing to take responsibility to see that the data were fully exploited. At present local groups are interested in the Arctic and Antarctic, Equatorial zone and the Cape magnetic anomaly zone.

3.5. New Projects

If the requirements of the new science of ionospheric meteorology are to be met, regional networks of stations at least are needed with a spacing not exceeding 1000 km. For intensive scientific studies a spacing of about 500-700 km is desirable. Real time ionospheric forecasting could also require a similar spacing. Most satellite investigations also require a more efficient network of stations. In our view such projects should be encouraged by the development of simplified methods of sounding capable of giving a few simple parameters in a form directly usable by computers. Rapid data acquisition, transmission and processing is essential. We feel that several modern developments, e.g., ray tracing programs, will not get very far practically until medium scale ionospheric phenomena are better monitored and understood.

3.6. Views of Consultants on V.I. Network

The general opinion of our Consultants is:

(a) that the number of stations in the Southern Hemisphere is seriously inadequate,

(b) that there is a special interest in new stations in and bordering the South-Atlantic magnetic anomaly,

(c) that there is special interest in stations at latitudes where interaction between the ionosphere and magnetospheric tail are probable,

(d) that there is need for more Oceanic stations,

(e) that the possibility of increasing the number of conjugate pairs of stations be supported,

(f) that the rapid changes in critical frequency, height and shape of the F layer with both latitude, longitude and time in the equatorial zone justify a close network in this area to investigate the forces acting and to describe the phenomena for operational purposes.

3.7. Use of Backscatter, Oblique Incidence and Satellite Data to Supplement the V.I. Network

Our enquiries on these points showed much disagreement of the value of these techniques for practical problems; fairly common comments by CCIR groups being that they were usually only of value for scientific purposes with URSI groups expressing the converse view! Where used by highly skilled staff in carefully controlled projects backscatter and oblique incidence soundings have been very successful and have considerable possibilites for the future but at present the techniques have not been worked out which would make them economical replacements of the VI network or even preferred methods of extending it except in special circumstances.

Our views on use of satellites have been given in the URSI report to CCIR. Experience since that report was written suggests that simple satellite data, if taped so as to be available from all parts of the world, could be invaluable for survey purposes, showing where stations ought to be maintained or established, but may need some years of detailed satellite-ground station comparisons before the interpolation laws are well understood, preferably from a stronger ground-based chain of stations than is at present available. However satellites flying above hmF2 can never give direct information about the important forces acting at lower levels.

4. Working Group Proposals

4.1. Networks

The working group believes that the needs of future scientific work involving the ionosphere could be most efficiently met by providing three complementary systems of stations:

(a) A limited number of key stations using the most accurate and advanced types of equipment available, producing data of the highest quality and backed up by advanced analysis techniques. The majority of these stations will tend to be at major ionospheric research institutes, rocket ranges or incoherent scatter stations though some such equipment

should be available for special investigations, under the guidance of expert teams, in other parts of the world. The planning, deployment and use of such stations can be reasonably left to the research groups involved. A number of these stations will also be required at places dictated by ionospheric phenomena for long term synoptic studies, whether a suitable institute is available or not, and should form the backbone of the synoptic system. A main responsibility of such stations would be to be able to provide highly accurate data for studies of particular events.

(b) A basic network of stations, comparable in size and distribution to the existing network, whose main objective would be to take observatory type observations of standard parameters, very complete in time so as to monitor the environment. Current types of equipment, when properly installed and operated, serve this purpose fairly adequately, but most of these are now obsolete or wearing out and new equipments are badly needed. Some redeployment to monitor areas where ionisation gradients are large would be very valuable. Improvements in reliability, signal-to-noise ratio, readability of records and in the training of analysis staff are needed for the network to be effective.

(c) Networks of highly simplified automatic or semi-automatic recorders capable of giving selected limited parameters in forms directly usable in computer analysis. These are needed:

(i) for morphological studies of phenomena which vary rapidly with position on the earth (e..g., F region meteorology),

(ii) to obtain data from regions which are difficult or expensive to monitor with manned stations,

(iii) to obtain CCIR prediction data.

Probably many existing stations could be refitted with these recorders with advantage.

The main weakness of the existing network of stations is that too many stations which are important links in the main morphological chains produce data which are too incomplete or too poor in quality to be useful for scientific or CCIR purposes. This difficulty is most evident in stations in developing countries and in the Southern Hemisphere. Action is urgently required.

Regarded as empirical exercises, the CCIR requirements are for:

(a) a group of monitoring index stations,

(b) continuity of operation of existing stations over at least one solar cycle,

(c) gap filling stations particularly in ocean areas,

(d) intensive study of areas where there are great gradients of ionization,

(e) the exploration of whether real time forecasting is feasible and can be done economically.

In our view these requirements could be met efficiently by the proposals above.

4.2. Areas with Highest Priority

We wish to stress that the possibilities for establishing new stations in the near future are very limited and depend on logistical possibilities as well as scientific need. In present circumstances the case for setting up a station where there are no existing facilities to work and live needs to be extremely strong before it is possible for international bodies to endorse it and even where some facilities exist it is usually not sufficient to say that it is needed to help a particular research. If possible the support of an international symposium with expert interest in the proposals should be sought. A very good example of the type of case needed has been prepared by the New Zealand group and is given in Annex 2 as an example.

We suggest that any available effort to establish new stations or improve old ones be concentrated in the zones needed to help current growing points.

We select the following:

(a) Worldwide morphology combining satellite and ground data. Here we feel that the satellites will show where stations are most needed and, until that is clear, the case for stations in special areas cannot be established. In general this type of study proceeds by a satellite survey, evaluated and controlled by wide spaced ground stations, followed by the usual hypothesis and special test procedure. At this stage, any station giving reliable data is valuable. The most economical method of aiding these projects would be to improve the quality and completeness of data from existing stations particularly in the Southern Hemisphere and where the separation in longitude is large. We regard this as a very high priority.

(b) Studies of the morphology and physics of the Equatorial anomaly zone.

(c) Studies of ionospheric high energy particle relations

(i) in the South Atlantic magnetic anomaly zone

(ii) in auroral and subauroral regions

(d) Studies of conjugate phenomena at both conjugate points and along conjugate shells.

(e) Studies of ionospheric-magnetospheric interactions.

(f) Studies of ionospheric meteorology.

In all of these there is much active research, a common pattern being the combination of intensive studies using complex techniques at particular points with survey experiments in space and time using simpler, and usually synoptic measurements.

Examining the work in progress we note that the existence of suitable facilities has been more important in deciding which problems are tackled first than theoretical guidance. We feel that this may well be so in the future also and that the best way of helping the future scientist is to consider how the information can be most efficiently obtained in the future. Such techniques need to be fully developed before they are adopted internationally and pending such development we feel that the existing network provides the cheapest and most efficient system at present available. Thus we recommend:

(a) The maintenance of the existing network,

(b) Action to improve its efficiency and accuracy,

(c) Limited extension where the logistic difficulties are not too great and the scientific cooperational need is well established.

This is essentially a holding operation while more efficient systems can be developed.

Particularly in view of the active interaction between space projects and ionospheric studies we feel that we can recommend to administrations the need to improve existing stations and, where practical, install new ones.

4.3. High Quality Stations

We are seriously alarmed by the low standards of operation of the majority of synoptic ionospheric stations in the world and feel that the future of ionospheric science may be jeopardised by this weakness. We therefore stress that the acquisition of long sequences of accurate data is essential.

In the past, the URSI/IQSY and URSI/CIG committees have recommended the nomination of key stations to meet this difficulty. This still seems the logical solution though experience has shown that few administrations have been willing to nominate any stations as key stations and maintain the standards implied.

Scientifically, the greatest value could be obtained from such stations if most were associated with important centres of research in the field. This, however, raises financial and psychological problems which, unless faced, are likely to prevent the maintenance of the high standards needed. The primary needs are:

(a) Adequate equipment,

(b) Suitable staff with proper training, interested in maintaining standards and prepared to stay with the job for many years,

(c) Attention to maintaining morale,

(d) Permanent long term funding.

Points (b) and (d) give particular trouble in stations linked with Universities, (c) needs attention everywhere as the staff involved tend to be cut off from the rest of their colleagues, who often do not understand the need or value of their work. In the past in other fields this difficulty has been overcome by making the Observatory a prestige operation, e.g., Greenwich Observatory, Potsdam Magnetic Observatory, etc.

We recommend that administrations be invited to nominate stations for the role of key stations, the act of nomination involving the duty of maintaining a high standard of operation, completeness of data, proper training of staff, strict observance of international rules of interpretation, quick circulation of data and acceptance of independent checking of selected data on demand. A station should lose its key station status if the checks showed that the data were not of the required standard. This would provide a sample of reliable data that independent scientists could use without misgivings on accuracy and interpretation -- their most common request.

The main difficulty will be to get enough widely distributed key stations to satisfy reasonable scientific needs. We also wish to encourage cooperation between stations so that key sequences are maintained and suggest that, where two stations are sufficiently close for the data to be highly correlated, they collaborate to this end, warning each other of breakdowns or probable periods of non-operation.

4.4. Provision of Equipment

Turning to the more distant future we feel that serious efforts should be made to establish techniques whereby the data required, particularly for ionospheric meteorological, morphological studies and practical application, could be provided more cheaply and with less use of expensive manpower.

We believe that there are really several separate types of problem to be solved:

(a) The maintenance of a group of key ionospheric stations giving very detailed high accuracy data. Equipment for this purpose is being developed or produced by several groups.

(b) Some general purpose observatory equipments, capable of being operated cheaply and reliably in developing countries to give data which can be used for a wide range of local studies. This needs more attention as most available equipments are too costly and unnecessarily complex for the purpose.

(c) The provision of cheap, semi-automatic or automatic equipments giving very complete data on a limited number of parameters in a form easily handled by computers but not necessarily having very high accuracy. We know of no projects to solve this problem cheaply.

Suggestion (c) has aroused considerable support, more than twelve groups have expressed interest, the general view being that the proposal should be discussed at length, note being taken of the possibility of cutting costs by modular methods so that a range of equipments could be provided with many common features.

In our view too little attention has been given to the problem of data handling and this prevents the full exploitation even of existing techniques. This is particularly important in the use of oblique incidence measurements (OI) backscatter and, to a lesser extent, satellite observations and has largely prevented the economic exploitation of the large amount of accurate ionisation height measurements which have been made. Surprisingly little use has been made of the powerful technique of automatic monitoring of selected parameters, largely through the same cause.

We foresee three difficulties in the development of new equipment:

(a) Where the technique is designed for a special purpose, e.g., 'chirp', the optimum design for synoptic or observatory work is usually different to that chosen by the expert group involved who may have little interest in extending the technique to other problems and often inadequate knowledge to recognise the best compromises.

(b) Where the final equipment is to be simple and cheap few engineers are interested in attempting the design. Unless this is good the project will fail.

(c) The market for specialised equipments will not exist until they have been developed and proved and scientists cannot say whether they would be interested without a reasonably firm estimate of cost. This development is not commercially practical without an assured market.

There has been little public debate on the possible solutions all of which have disadvantages as well as advantages. Some possibilities are:

(a) The adoption of a development programme by a National Laboratory as a prestige operation in international collaboration.

(b) The transfer of the operations of the synoptic network to a large and rich organisation capable of financing the necessary work. Our consultants have suggested WMO as a possible candidate but it is not obvious that the finance and technical facilities would be available.

(c) Wait with the hope that a wealthy organisation will do the necessary work for its own purposes and then adapt the equipment produced.

4.5. Data Accuracy and Quality

We are frequently asked how independent scientists can know which data may be relied on (the rather few prediction and morphological experts know this by experience but are also often not up-to-date in their judgments). In principle, all stations collaborating in the synoptic network are supposed to obey the international rules unless they state the exceptions when circulating their data. In practice many do not have the skill and facilities to do this properly. We recommend that stations who feel able to guarantee satisfying the rules have the right to mark their data with a quality symbol but, if they do so, must submit sample sequences or ionograms on demand for random checking of the claim and desist from using the quality symbol when the claim is not substantiated. This appears to be the best way of maximising the amount of reliable data for theleast amount of checking. The criteria and conditions for using quality symbols should be worked out by the VI Consultant or a special working group as thought preferable, e.g., some stations might be able to meet the required standards for certain parameters only.

In view of the difficulties which have arisen in setting up a key station network in the past, we suggest that this proposal be considered as an alternative to the key station proposal as well as an addition to it.

All groups which use data and have reported to us stress that their researches, particularly into events, are badly hampered by gaps in numerical data. Several point out that medians based on less than about half the possible number of entries are frequently misleading. We concur and note that, in foF2, at least 65 stations out of 135 showed some hours with medians with counts less than 15 during June or December 1958 and the number of hours per day when this was found averaged 10 and with a median value of 8 hours per station involved. In these cases even the averaged data abstracted for CCIR and morphological purposes are likely to be seriously misleading.

We do not believe that these difficulties can be solved adequately without the provision of visiting experts, as has been done for the chain of magnetic stations and recommend accordingly.

5. Future Organisation of the VI Network

There is widespread criticism of the operation and deployment of the VI network, the general feeling amongst our consultants being that more international aid is needed. Most detailed suggestions for improvements which we have received appear to require such aid.

In general, data flow from stations is now very slow, and morale at many routine stations is low. Although the centre of gravity of ionospheric research has tended to move away from vertical soundings, the greatest demand for data from the WDCs continues to be for vertical incidence data. There is a continuing need, particularly for theoretical studies, to improve the quality of ionograms.

Our consultants appear to favour, roughly equally, two alternatives:

(a) To meet urgent needs by improvised means hoping that these would grow into a more permanent and effective organisation.

(b) To attempt to centralise the administration and control by either setting up a new organisation similar to the WMO or by joining an existing organisation capable of financing the station monitoring and development of new equipment.

There is a widespread view that at least one permanent full-time expert is needed to help run the network and monitor its behaviour. The greatest weakness of the existing system is the unreliability and incompleteness of the data, particularly from advancing countries.

There is need for two types of aid to stations:

(i) For most stations, a visiting reporter who could solve station problems, make sure that current analysis procedures gave data consistent with the URSI rules, and encourage morale, e.g., by showing how the data produced had been used.

(ii) At some stations, particularly in developing countries, visits by an engineer with expert knowledge of the type of ionosonde in use, to put the equipment into efficient operation and to advise on technical problems.

In both cases the visit should be long enough to solve the current problems. Tests are also needed to establish the uniformity of the data particularly when used for prediction purposes, e.g., sporadic E, height and M3000 data appear suspiciously inconsistent from station to station.

We feel strong efforts should be made, possibly through UNESCO, to send an expert to visit at least the main chains of stations in advancing countries and that the views of station administrations should be sought to find out whether a more ambitious programme be adopted.

6. URSI-STP Recommendations

A number of our recommendations have been discussed in detail at the Brussels meeting of the URSI-STP Committee, September 1968, adopted by that Committee and published in the URSI Information Bulletin, No. 169, December 1968, pp. 48-59. These are reproduced below.

Rec. (3) New Ionosondes

The URSI-STP Committee draws attention to the fact that the ionosondes in use at many synoptic stations are obsolete, or wearing out, or both, and that there is an urgent need to provide for their replacement by modern equipment.

Depending on local conditions, the main requirements are for:

(a) A number of highly accurate equipments, using either conventional or modern techniques.

(b) A larger number of cheap observatory-type instruments capable of high reliability.

(c) A still larger number of very simplified cheap sounders capable of recording a few parameters only and producing the results in a form suitable for computer handling.

Rec. (4) Use of V.I. Data

The URSI-STP Committee requests those using synoptic data for scientific purposes to send copies of any published papers or preprints to the administrations responsible for producing the original data.

Rec. (5) Synoptic Network for V.I. Soundings

The URSI-STP Committee, having considered the views of those who produce and use vertical incidence soundings data, recommends that all V.I. stations be encouraged to participate in intensive studies of regional and other problems and that a strong effort be made to increase the degree of flexibility in the V.I. network to meet the changing needs of international cooperation and of coordination with space experiments. The URSI-STP Committee further recommends that a number of stations be identified by consultation with countries interested in the possibility of developing these stations to meet high standards of quality at a limited number of locations.

Rec. (6) Spread F Index

The URSI-STP Committee, noting that a measure of the top frequency of Spread F is urgently required for CCIR purposes and also has scientific interest, and that a proposal to introduce such an index has

been widely supported by those responsible for stations, recommends that a new ionospheric parameter denoted fxI (with computer symbol 51) be adopted for international analysis, tabulation and normal circulation through WDCs and other publication methods, defined and applied according to the instructions following. It is recommended that all stations at high latitudes or subject to equatorial spread F tabulate and circulate this parameter, and that stations at other latitudes be invited to volunteer to analyse the parameter as a trial. Tests are particularly important at stations where the spread of frequencies of spread F often exceeds fH/2 at certain hours.

The URSI-STP Committee further recommends that stations report the properties of the new parameter in the scientific literature, through STP Notes, or through the URSI V.I. Consultant (Mr. W. R. Piggott, Radio and Space Research Station, Slough, Bucks., U.K.), and that its operation be reviewed at the next General Assembly of URSI where any suggested modifications can be considered and approved. It is recommended that this resolution be brought to the attention of CCIR, who should request administrations to adopt this index.

The parameter fxI

Definition

The parameter fxI is defined as the highest frequency on which reflections from the F region are recorded, independent of whether they are reflected overhead or at oblique incidence. Thus, fxI is the top frequency of spread F traces including polar or equatorial spurs, but not including ground backscatter traces.

Scaling Rules

1. The normal descriptive letter symbols should be used to show the reasons for absent entries, but the accuracy rules do not apply for this parameter.

2. Monthly tabulation sheets should be left blank for columns at hours at which spread F traces are seldom or never seen as is the practice for E and F1 parameters.

3. The use of replacement letter B, or descriptive letter B, should be determined by the same procedure as that given for foEs in the "URSI Handbook of Ionogram Interpretation."

(a) If the scatter traces disappear as a result of high absorption, use replacement letter B.

(b) If fminx is above the top frequency seen (see foEs rules) add fH/2 to the top frequency, and add qualifying letter O, descriptive letter B.

(c) If fmin is high, showing large absorption, but the value of fminx cannot easily be determined, use qualifying letter M (interpretation doubtful: reading may be foI instead of fxI) and descriptive letter B.

(i) When the signal/noise ratio is low, fxI is power sensitive; when high, it is independent of power as far as is known at present. For ionosondes with low signal/noise ratio for normal absorption the extra work in computing fxI from foI may not be justified.

(ii) Special care is needed when foI is near or below fH, since absorption can then hide fxI.

Rec. (7) Mapping Particular Ionospheric Phenomena

The URSI-STP Committee draws the attention of scientists to the need of the CCIR to map the zones, in space and time, where particular ionospheric phenomena occur and to establish the laws connecting related phenomena at different locations.

Rec. (8) Station Codes

The URSI-STP Committee recommends that the station codes at present in use at ESSA, WDC-A, be adopted as the standard station indicators for computer identification. All stations changing to computer methods of data handling are requested to obtain code numbers from ESSA, WDC-A, Boulder, Colorado, U.S.A.

7. Points for Discussion at London Meeting

As can be seen from its report and recommendations (URSI Information Bulletin No. 169, December 1968, pp. 48-59), the URSI-STP Committee has accepted in essence the main points of the Report of the Working Group, reproduced in abbreviated form here and has recommended a meeting at London of those responsible for station networks to consider some aspects of this report and decide on any necessary action.

7.1. Immediate Needs of Network

The current performance of the VI network is highly unsatisfactory with much missing or low quality data, slow data flow from many stations, and low morale at many stations. Most researchers using chains of stations are crippled by inadequate performance of some stations in the chain.

The most immediate problem is to improve this situation.

Points for discussion:

(1) (a) Desirability of providing a travelling consultant at least to main chains of stations.

(b) Possibility of local organisations arranging for such support for own stations and those logistically linked with them.

(c) Methods of financing such proposals.

(2) Possibility of improving standards at stations by local action:

(a) Monitoring data

(b) Training staff

(c) Improvement of existing equipment or provision of new.

(3) Problem of morale at stations:

(a) International or regional collaboration.

(b) Feedback from WDCs or those using data.

(c) Encouragement of regional conferences.

(d) Use of URSI or CCIR organisation.

7.2. Scale and Deployment of Network-short Term

The maintenance of the network involves considerable costs in manpower and money. The views of those providing this are essential.

1. Desirability of maintaining existing network in essentially present form for a further period of time.

2. Possibility of gap-filling or redeployment of existing stations.

3. Possibility of decreasing costs by computerised methods of handling data.

4. Desirability of key stations and nominations for these.

5. Balancing international and local needs.

7.3. Future scale of network

The level of expenditure desirable for the long term future needs discussion.

1. Needs for production of long term synoptic data.

2. Needs for support of ad hoc experiments.

3. Needs for ionospheric meteorology, short time forecasts and similar problems.

7.4. Provision of Equipment

In general those using equipment and those capable of designing and building it have little contact.

1. How to improve this situation.

2. Statements of what is required.

7.5. Organisation of a Permanent Network

Is the present system of voluntary part time advisors adequate? If not, what type of organisation would be acceptable to the administrations and give an efficient system? Should there be a full time staff and if so, how should it be financed?

7.6. Particular Difficulties Needing Attention

To be raised by representatives and VI consultants if time allows.

Appendix 3

(Circular issued in 1967 by Vertical Soundings Consultant)

Subjects: (a) Distribution, location and programme of ionospheric soundings stations, vertical and oblique incidence for scientific studies.

(b) Recommendations of CCIR on distribution location and programme of ionospheric soundings stations and on the use of other techniques (topside soundings backscatter, etc.) for improving the use of LF, MF and HF communications.

* * * *

Dear Colleague:

At the Munich General Assembly, Commission III recommended the establishment of a small working group to consider the above questions and to be convened by the Vertical Incidence Consultant (URSI Information Bulletin No. 159, Rec. III,1; III,2; III,5; pp. 5, 7, 10, 20, 21, 24). It requested a report summarizing the points of view of all major institutions involved and all interested workers from the fields of Radio Science, Geophysics and Space Science.

As Convenor, I am writing to ask for your views on questions (a) and (b) above and in particular for any requests you may have for the maintenance, establishment or change in programme at stations not under your control.

In order to start discussion, I enclose herewith:

(i) A note "Some Considerations Concerning the VI Ionospheric Soundings Network After the IQSY,"

(ii) A note, "Supplementing the World Network of Ionospheric Data for CCIR Purposes,"

(iii) A questionnaire,

(iv) Some personal views from the VI Consultant on points of detail.

Copies of the URSI Recommendations and the CCIR Opinions, Questions, Reports and Recommendations to be considered by the working group can be obtained from the VI Consultant on request.

This working party exists to collect and synthesize your ideas on what is desirable and needed, and it is important that its reports be based on a wide consensus of opinion. I hope therefore that you will attempt some reply, particularly if you object to or support any of the remarks made in the attached documents.

Yours sincerely,

(signed) W. R. Piggott (VI Consultant)

Document I

Some Considerations Concerning the Vertical Incidence Ionospheric Soundings Network After the IQSY

The following notes on a post-IQSY soundings network have been prepared for the Prague meeting of IUCSTP by Mr. W.R. Piggott, URSI Consultant for vertical incidence soundings.

There is need for informed international guidance on the deployment and programme of the Vertical Incidence (VI) Sounding network after the IQSY. For this purpose it is necessary to estimate the scientific and operational requirements taking into account the interaction between ground-based ionospheric data and those obtained by other means or in other disciplines. Your views are sought.

After the IGY, many scientists felt that the network should be reduced from the IGY level of 167 stations to well below the pre-IGY level of 99 stations (1956). In fact it fell to a minimum of 133 active stations in 1962-4 and has since increased to at least 158 stations. After some experimenting with reduced programmes, data analysis and publications after the IGC, most stations have reverted to programmes close to those done in the IGY and they publish at least hourly data.

The high level of activity appears to be mainly due to the following factors:

(a) A detailed knowledge of the behaviour of the bottom side of the ionosphere is, in practice, essential for the understanding of the physics of the ionosphere.

(b) Vertical incidence sounding is the cheapest and most efficient method of obtaining detailed information about the ionosphere both for local and synoptic purposes up to the height of maximum of the F2 layer.

(c) The need for current VI synoptic data to interpret the results of expensive space projects.

(d) The great increase in the number of workers studying the VI data, both for itself and in conjunction with space projects, has increased the demand for more data and has stimulated interest in obtaining it.

(e) The pressure from these workers for additional stations, in order to assist the study of particular scientific or operational problems, has increased the network.

The main problem in the use of existing data is that the ionosphere varies very greatly from occasion to occasion; e.g., for the world as a whole, ionospheric conditions on two quiet or two disturbed days may differ from each other by more than the difference for an average quiet and an average disturbed day. Thus there is a continuing need for synoptic data to compare with the results both of new techniques and of ad hoc experiments.

The main demands for long-term frequency prediction purposes are:

(a) the maintenance of certain key stations indefinitely;

(b) redeployment of stations to zones where little data are available for, preferably, a period including both solar maximum and solar minimum conditions. Critical frequencies, heights of maximum electron density and amount of sporadic E are particularly important.

Short-term forecasts demand the continuance of local observations, in addition to a certain minimum network of collaborating stations at other latitudes and longitudes, to give early warning from precursors of storm phenomena.

At present the main scientific applications seem to be to problems of the forces determining the electron distribution with height and position. There is much interest in possible dynamic interactions between the neutral atmosphere and the ionization, and between the magnetosphere and ionization. Particular problems include the interpretation of the results of topside sounding, the equatorial anomaly; Cape or Weddell Sea anomaly; conjugate-point problems; Arctic and Antarctic research. The workers involved are pressing for more or differently placed stations with stress on chains of stations in particular localities.

So far as the F2 layer is concerned, the morphology could be studied efficiently by combining two out of three of the following:

(a) topside sounders in near circular polar orbits;

(b) topside sounders in near circular equatorial orbits;

(c) a ground-based network.

Some gap filling may be possible using backscatter and oblique incidence sounding but the data obtained depend on both height and ionization changes and cannot be interpreted in regions where conditions change rapidly with distance. Methods of using such data synoptically have still to be developed.

While the current deployment is by no means ideal for either scientific or operational purposes, there are very few locations where there is serious duplication and there are great logistic difficulties in transferring staff and equipment from one country to another. Thus the main practical problem is to decide how much of the existing chain should be maintained; it is unlikely that many significant improvements in deployment could be made in the near future. Most new preferred sites are in positions where stations would have to be set up and maintained by organizations with considerable resources.

An important operational factor is that most synoptic stations are manned by staff selected to make synoptic measurements, but who are ill equipped for research. In practice, there is little opportunity to replace synoptic by ad hoc research using the same staff and equipment. Such staff could be employed, after retraining, for topside synoptic problems.

The best deployment of VI soundings stations should be influenced by the policy in launching ionospheric satellites, in particular those carrying topside sounders. This refers to both the policy in launching such satellites and to the provision of staff for working out synoptic data from their observations. At present such satellites are used only for research projects and a great increase (probably by a factor of 10) in staff employed on analysis will be needed if synoptic data are to be made available. Until this can be ensured, it is wisest to keep the existing ground network working as fully as possible.

A strong ground network is particularly important when most of the satellite work employs polar orbits since such satellites give great detail of the latitudinal variations at nearly constant local time, but at any latitude the interpretation of the actual conditions depends on the time sequence at that location. In contrast, similar satellites in nearly equatorial orbits can rapidly build up the diurnal variations over a wide range of longitudes but for a more restricted range of latitudes.

In general it appears that the applications of the VI network are at least as important as those of the magnetic network and there is probably even more detailed analysis being done using VI data than magnetic data. Networks of comparable size appear to be scientifically justified.

Document II

Supplementing the World Network of Ionospheric Data for CCIR Purposes

1. General

The proposals set out below are intended solely to start discussion and do not represent considered opinions.

CCIR ionospheric problems fall into three main classes:

(a) Improvement of long-term predictions. Here the main weaknesses are gaps in data in large areas, and correct description of gradients where conditions change rapidly with position.

(b) Forecasts of disturbance or best way of changing frequency to use available band most efficiently on a short-time basis.

(c) Design and use of high reliability circuits where considerable sophistication is possible and economically useful.

While data obtained for any of these can, in principle, be used in the others, the costs of obtaining it increase rapidly with complexity.

2. Predictions

The ionosphere has been sampled at reasonable spacings over about half its area. For F region predictions it is necessary to know critical frequency, foF2, and the height of maximum electron density, hmF2, or parameters giving equivalent information, foF2, M3000F2; foF2, MUF(3000)F2, etc. In addition, there is need for measurements of sporadic E. Filling the gaps by deploying conventional ionosondes would be very expensive.

There is a possibility that cheap, reliable semi-automatic equipment could be designed to give very limited information of the types required. This would probably not be usable when the ionospheric conditions were very complex but would nevertheless fill most CCIR requirements from the remainder of the working time.

According to local conditions either recording for, say, one month, on magnetic tape of the required parameters would be made or data could be sent back by telemetry at more frequent intervals. There is evidence that the top frequency of spread F is the important parameter for CCIR purposes and this could be given relatively easily when the critical frequency was not observable.

Your comments and suggestions for such an instrument are invited and any points of detail, e.g., choice of parameters to be measured, rate of observation, data handling, etc.

Worthwhile data could probably be obtained cheaply by satellite methods also, but again the instrument and orbit would be very different to that chosen for scientific studies. Comments on requirements, rate of observation, orbit, etc. are invited. A preliminary suggestion would be to measure:

(a) critical frequency or top frequency of spread echoes or sporadic E

(b) plasma frequency at satellite

(c) one height parameter

at, say, every 100 km along path.

The amount of data collected per orbit could easily be handled by a solid state memory system and telemetered to ground at convenient intervals.

3. Combination of Techniques

In some sectors it would be possible to combine techniques to give data useful for prediction purposes. Thus the two independent F region parameters could be measured combining:

(a) satellite measurements of critical frequency

with

(b) oblique incidence MUF measurements

or

(c) oblique incidence backscatter measurements.

Such combinations would need organization so that data was properly linked together and analyzed.

The use of (b) and (c) and sporadic E studies needs stressing. Data exist but have seldom been collected in a form suitable for CCIR purposes.

4. Forecasts

There is considerable discussion on the desirability of setting up forecasting networks at present and some have, in fact, been set up and operated for a year or more. Immediately these would be based on conventional ionosonde stations, but the possibility of using simplified automatic stations in the future needs discussion. Are you interested in collaborating in or using such systems?

5. Sophisticated Systems

In general the cost of sophisticated systems is very large compared with the cost of scientific research. The important points here appear to be:

(a) To ensure that data obtained are tabulated in a usable form for prediction purposes.

(b) To use the data regionally to give local forecast services.

Particularly (b) would appear to give a larger return in efficiency of use of the HF spectrum for marginal increases in cost.

6. Most CCIR problems are not directly interesting to scientists, yet need some specialized knowledge for solution. The slow progress in the last 20 years suggests that they can only be solved by bringing in new workers. I would like to suggest a close liaison between universities, government departments and operating agencies having this specialized knowledge and engineering departments, colleges of advanced technology, technical high schools and similar bodies where engineers are trained in these fields.

Many of the problems could be broken down into good projects, valuable both to the engineering student and giving data usable for CCIR purposes. Your comments are invited.

Document III

Note: Numbers give number of written replies received on each point.

Please return to:

Mr. W. R. Piggott, VI Consultant
Radio and Space Research Station
Ditton Park
Slough, Bucks., England

(Leave blank if you have no opinion). 33 replies.

Do you feel that the present network of VI and OI stations is:

VI adequate - 21	too small - 2	too large - 3
OI " - 3	" " - 3	" " - 0

Suggested size: VI - OI -

Are there particular stations whose operation you wish to see continued in the future? Please name:

Are there gaps which you wish to see filled for (a) Scientific, (b) Operational reasons?

Suggested sites:

Are you prepared to keep stations operating under your control working in future?

(a) To present programme - 16

(b) With fuller programme - 7

(c) With smaller programme - 0

Stations involved:

Do you wish to contribute to or receive any further documents from this Working Party? YES - 31 NO - 1

Comments on document (i) 20

Comments on document (ii) 14

Comments on other subjects (iv) 13

Name:
Address:

Document IV

Comments on the Current Operation of the VI Network

(a) Probably little can be done to extend the standard network though some local redeployment may be possible in a few areas where there is strong scientific interest in regional or conjugate point studies.

(b) Taking into account that we must provide for future, at present unforeseen, research and for expensive space projects, the network seems to be about the right size.

(c) The real weakness is that the data from a large number of stations is seriously unreliable or incomplete. This occurs partly because many stations are using aerials which are much too small, partly due to inefficient servicing and partly to insufficient attention to or misunderstanding of the international data reduction rules. In particular median values of foEs, fbEs are frequently much too high, the absence of Es being explained by a letter symbol which does not enter the median; many stations confuse no echoes due to low critical frequencies with blackout (EE is replaced by B); and many replace a numerical value by a letter symbol too frequently when a numerical value could be given. Medians are of little scientific or practical use unless the count in a month is greater than half the possible values.

(d) There is a need for local groups to study their own and regional data in greater detail and to publish short summarizing papers.

(e) A number of stations make observations which are not analyzed and whose existence is unknown to most workers. It is important that the existence of these data be made known to the WDCs so that any wishing to use them can approach the organization involved and arrange for analysis (by themselves if necessary) of interesting events or for special purposes.

(f) Any serious attempt to improve HF communications significantly and cheaply will involve the use of new techniques or considerable modifications to existing methods.

(g) The really large gap operationally, and to a considerable extent scientifically, is in the measurement and morphology of ionospheric absorption.

(h) Some of the sophisticated systems of HF communication demand a knowledge of Doppler shift on different modes of propagation. This has received little attention from most scientific groups.

Appendix 4

1. Views of Consultants

1.1. Size of VI Network

The consensus of opinion of our consultants is fairly consistent and amounts to stating that the VI network should be maintained at approximately its present size, but with some revision of deployment, and that the absorption and drift networks should be expanded in the future.

The detailed replies to our questionnaire may be summarized as follows:

From 33 written replies:

26 replies gave answers on the size of the VI network,
21 thought it was about right
3 thought it was too small
2 thought it was too large

Consultants were asked to list stations they wished to have continued. The written lists have been rearranged in alphabetical order below together with suggested new stations (*). In addition the following general remarks have been received:

(a) "Stations in developing countries for the purpose of obtaining better and more reliable data from these areas. Africa was also mentioned specifically.

(b) "All stations in the equatorial region, arctic and antarctic (several groups collectively or specifically).

(c) "Concentrate on islands in oceans for control of predictions (several groups and CCIR).

(d) "Most stations in and on the vicinity of the auroral zone and some additional stations at lower latitudes, with good coverage where magnetospheric-ionospheric interaction may occur.

(e) "All Northern hemisphere soundings stations with the possible exception of certain European stations whose data coverage verges on duplication.

(f) "We have active research involving the use of ionospheric data from numerous stations over a widespread area and need as many of the existing stations as possible (summary of several groups).

(g) "Stations with long time series of ionograms for studies of weak tidal effects, synoptic changes and those included in the IF2 list.

(h) "Most basic pre-IQSY stations should be maintained and equipped with magnetometers for simultaneous ionospheric-magnetic observations."

(i) Station network. Since bottomside synoptic data are needed to supplement and interpret results from space measurements, it is recommended that the current station network should not be reduced. It would be very useful to establish new stations in the equatorial region, polar zones, and in the region where the negative magnetic Brazil anomaly exists.

(j) There is a reasonably good distribution of stations in the northern Asian zone, but there is a miserable lack of stations in the south, especially between the equator and the subtropical peak region. The establishment of stations in Ceylon, Indonesia and Burma should be encouraged.

(k) I would strongly recommend one ionospheric station near the magnetic equator in the eastern coast of Brazil. Natal has been operating for sometime but I have not seen any data after 1963. Even if it is still in operation, some assistance may be given to the station to improve the quality and quantity of its observations.

(l) Our recent analyses have shown a few remarkable anomalies in the Pacific zone where no equatorial station operated except Christmas Island during 1945-46. If possible one ionospheric station may be recommended at Christmas Island or any suitable near location.

The main departures from these estimates come from groups who have made a detailed study of their needs and, by implication, from the remarks of those with strong regional interests. Thus both Arctic and Antarctic workers point out that their chains of stations are inadequate for many problems and want temperate and low latitude stations moved to these zones; low latitude workers feel the same and want higher latitude stations moved to the equatorial anomaly zones. To meet both requirements simultaneously without the closing of existing stations would probably involve a network of about 220 stations, i.e., about twice as many as are available at present.

1.2. List of Stations whose Operation has been Requested by Consultants and their Proposals for New Stations*

Alert	Frobisher Bay	Macquari Is.*	Vostok
Akrotiri	Fort Chimo		Victoria B.C.
Ankara		Nurmijarvi	
Athens	Godley Head	Narsarssuak	Washington
Argentine Is.	Gauheti	Natal	Wadi Halfa
Adak*	Godhavn		Sudan*
Addis Ababa*	Garchy	Paramaribo	
Azores	Gorki	Poitiers	Yellowstone
Ascension Is.*	Gann Is.*	Port Moresby	
		Puerto Rico	Zaria
Baker Lake	Halley Bay	Port Stanley	
Bangui	Huancayo		
Budapest	Haifa*	Rome	
Beograd	Hyderabad	Reykjavik	
Bogata		Rostov	
Buenos Aires	Islands	Raratonga	
Byrd	Ibadan		
		Slough	
College		St. Johns	
Clyde River	Johannesburg	Simferopol	
Chita	Jammu	Sao Paulo	
Calcutta	Jarvis*	(obsolete equipment)	
Cocos Is.	Jan Mayen*	San Pablo	
Canberra		South Philippines	
Christmas Is.*	Kharborough	(near dip equator*)	
Colombo Ceylon	Kerquela	San Jose*	
		Sardinia* (ESRO)	
Dixon	Leopoldville		
Delhi	Longyearbyen	Tomsk	
Durban	Lwiro	Tokio	
Deception		Teheran	
Dar Es Salaam*	Maui	Tamanrasset	
Diego Garcia*	Mundaring (Watheroo)	Tbilisi	
	Miedzeszyn	Townsville	
Eureka	Meanock	Tsumeb	
Easter Is.*	Marion Is.*	Talara	
		Transequatorial	

In addition to the specific proposals given above for new VI stations our consultants:

(a) Stress the value and importance of more ship-borne ionosondes particularly in geophysical ships, weather ships and those making regular long voyages, e.g., oil tankers.

(b) Stress the value of aircraft-borne ionosondes and the need to publish data from this source.

(c) Stress the need for more absorption, drift and VLF observatories, and add the following general comments:

(d) The existing chains of stations should be strengthened where gradients are large and where possible, extended with particular emphasis on the following zones:

(i) increasing the density of stations near the peaks of the equatorial anomaly.

(ii) extending the USSR-Indian chain southward (e.g., Colombo, Gann, Diego Garcia).

(iii) extending the chain near 180° by establishing new stations on the latitude range 20°N to 70°S.

(iv) to complete a close transequatorial chain of stations along a meridian in Africa.

(v) to establish stations near and under the Antarctic auroral zone.

(e) More conjugate point stations are needed (e.g., Marion Island would be conjugate to Kuhlensburg).

(f) More island stations to fill ocean gaps particularly off the Western coasts of Europe and North Africa and in the Pacific.

(g) Combined new ground and ship stations in the South Atlantic magnetic anomaly zone.

(h) New stations are required in the following areas:

Near 60°-70°N 50°E	(USSR)
About 40°N 110°E	(China)
In the zone 90°-120°W; 10°-70°S.	

The wide range of requests illustrates the wide range of objects for which routine data are used. It must be remembered that the logistical difficulties in establishing new stations can be prohibitive and must be balanced against the scientific need.

1.3. Combined Views

In addition to the comments summarized above a number of consultants provided combined views which appear well worth wider circulation and are abstracted (with minor alterations and additions) below. They in general reflect needs for particular application.

(a) The problem of sources of financial support to defray operating costs of the VI soundings networks is fundamental to the solution of many of the problems you have noted. In this regard, I believe that existing VI networks should be encouraged to strive for a good working relationship with agencies such as the World Meteorological Organization, UNESCO, and the proposed International Solar-Terrestrial Service of the Inter-Union Commission on Solar-Terrestrial Physics. These groups have large resources for collecting and disseminating data from observations.

(b) With respect to the distribution of data among the networks it should be noted that, as with weather data, the frequent and timely dissemination of ionospheric data is vital to their ultimate operational use. The operational community is poorly served by anything less than the most rapid data flow possible for each type of ionospheric observation.

(c) We cannot get rid of some unreliable stations and the poor and unsupervised scaling. Only experience has taught us which stations are bad, and we do not use such stations. However, nobody wishes to offend such groups; hence every worker has to find out for himself what data he can trust.

(d) I believe we need about 30 key stations over the world. Such stations should be carefully selected on the basis of geographic location; a guaranty that the station will not be moved or closed; the equipment is kept in excellent condition; data reduction is done correctly according to the rules; reduction is supervised and checked. Data should be published within a short time. Data taken every 15 minutes and f plots should be available for all days at the Data Centers.

Such a system exists for climatological stations, for geomagnetism (only 12 stations are used for Kp index), geodesy and possibly other disciplines. It should be possible for ionospheric work.

The rest of the network should be considered supplementary. They should be required to take hourly data and deposit the data sheets and perhaps copies of the ionograms at the Data Centers. If they want to do more, that should be allowed but not required. I believe an overall network of 100 stations is sufficient, provided Ocean Island stations are encouraged, because large gaps exist over the oceans.

(e) I am not in favor of operating special networks under international control. Nobody looks at the data. However, if a group plans an experiment and if that group requires a good network for a short time, then we have a guarantee that they will look at the data and then and only then will the special effort pay off.

(f) It may be wise to attach the whole ionospheric forecast system to the weather organizations (Meteorological Office, Weather Bureau). They have a good and smooth international operation, based on long experience of international cooperation and an existing communication network.

(g) The most difficult point, in answering the questionnaire is to find out what stations intend to close down in the future. We tried to check this by the data which arrived in the last year, but, especially for Africa, we did not find a unique answer.

(h) We have done a lot of work on mapping, prediction methods, and forecasts and my feeling is that some agencies will press these developments. It requires money, not international organizations which offer only advice (the cheapest commodity) but no real help. Current developments use oblique sounders which can be controlled and the recordings scaled next to the computer. It will be helpful in the future to receive data from vertical ionograms in real time (as the "weather report") three or four times a day. I believe the ionospheric key stations will have to provide such information in the future. However, at present the methods have to be worked out for useful forecasts. Satellite measurements will also be used and Alouette type satellite data obtained especially over oceans and areas with no station or unreliable stations to fill the gap. The satellite should work continuously; and anybody should be able to receive the transmission, similar to present weather satellites.

(i) The present ionosondes are technically outmoded; new ones will be designed using solid state technology for most of its parts. New systems like the chirp sounder which are presently developed may even replace the pulse method. An instrument which measures the parameters from fmin to foF2 will always be needed for communication forecasts. However, for scientific studies, special techniques will always be needed and, therefore, developed.

(j) The ionosphere has already been observed by the vertical sounding method for more than 40 years. Now-a-days vertical sounding data are rarely used for their own sake -- they are needed more frequently in relation to other observations such as incoherent scatter, topside sounding, Faraday fading observations, riometer observations, etc. Where such observations are made, the laboratories themselves look into the possibility of running an ionosonde in conjunction with their experiments. For the purpose of routine vigilance of the ionosphere a network of evenly distributed stations will do. The stations selected should be in a position to provide reliable data to anyone interested at a moderate cost and within a reasonable time. Huancayo should continue to operate both for routine vigilance as well as to support the many other observations that are part of the programs at Huancayo.

We believe that the Huancayo ionospheric soundings have been of high quality, continuous, made available to the world community, and that the personnel is highly qualified. It must be pointed out that this station has operated with the support of the Department of Terrestrial Magnetism,

through 1947, and since then with the financial support of ESSA, Boulder (formerly CRPL). Without this support, funds and material, the Instituto could not keep the station in operation. This is the case for the Talara sounder which requires some support, as yet unavailable.

(k) I fully agree that it is necessary to revise the present practice of vertical incidence recording and scaling. Though I cannot personally engage in this question any longer, I should like to make the following comments:

(i) Vertical incidence recordings should be regarded as primarily for scientific, local, and global studies, rather than as data collections for radio propagation predictions.

(ii) If this is not possible to achieve, one should make a distinction between stations operating for scientific purposes and those operating for prediction purposes, and those serving both kinds of operation.

1.4 Suggestions for Detailed Improvements

(a) The great weakness of the existing network is unreliability of the data, particularly those from advancing countries. We suggest that the rules contained in the URSI Handbook should be made available at all VI stations and to all staff analyzing ionograms. Some stations have difficulty in acquiring copies of the Handbook either through lack of foreign exchange or because of its high cost. All stations should state whether they have adopted the URSI Rules and accurately describe any local discrepancies. The possibility of circulating a cheap, expendable version of the Rules should be considered.

(b) I particularly want to stress the need to call the attention of the national Commissions of CIG on the unreliability of the data provided by one (or more) of their stations; it is necessary to demonstrate, with some examples, the nature of the errors by them introduced in the analysis of the data (or of the wrong working of their equipments)?

(c) There is a lot of dissimilarity in the tabulations of spread F and sporadic E data, both of which can be affected by the power of the ionosonde and on the antenna used. I should like your committee to formulate some suggestions which may enable intercomparison of these data from different stations.

(d) The rules for scaling should be revised. As one concrete proposal I should like to add a column on the data sheets for "observed phenomena." In this column one could note, according to a special "key," a large number of events, which are observed but usually not included in the forms. Such remarks could include what perhaps is more interesting than

critical frequencies and heights: spread phenomena of different kinds, sudden events, characteristics of sporadic layers, D-region reflections, etc. I would suggest that just a more interesting mode of scaling would improve the "morale" in handling both equipment and data.

(e) Atlas of Ionograms. It is desirable to begin the compilation of a third Atlas of Ionograms to show in detail the typical and distinctive features of the ionosphere at different latitudes under normal and disturbed conditions (spread F, stratifications, forked trace, E2-, FO-, F1.5-layer, SIDs, and other miscellaneous ionograms illustrating special sequences of interest). We feel that URSI should set up a small working group to write a guide to scientists on the main limitations of the data, e.g., effects of tilts, spurs, secondary layers and, in particular, the use and misuse of fmin and Es data.

2. A Model Case for New Stations

The working group feels that no administration should be asked to set up new stations without at least a minimum numerical case as given by the New Zealand group.

We took advantage of a recent symposium to sound out New Zealand opinion on the placing of ionosondes for scientific studies. The strongest plea was made for opening Macquarie Island again. The reasons are given below together with comments on other desirable sitings.

Macquarie Island

1. Fills a gap between Australia and Antarctica.

2. Need an ionosonde sited with the magnetometer.

3. Need an ionosonde near the crossing point of the auroral radar beams from Invercargill and Tasmania.

4. For use together with Campbell Island in deducing the size of current cells during disturbance.

5. To observe atmospheric waves generated in auroral activity.

6. To help in the interpretation of satellite recordings made on the island.

7. To be an approximate conjugate to Alaska.

It was pointed out that Campbell Island and Macquarie Island should not be regarded as alternatives but as complementary stations. Macquarie should be a permanent station.

The main weakness of this case is that it does not examine the cost of reopening the station.

Jarvis Island

1. Under the electrojet making it especially useful for studying low latitude sporadic E.

2. Midpoint of the conjugate pair - Rarotonga and Maui.

3. Following from (2), useful in studies of low latitude F region.

4. Useful in studies of intertropical arcs in airglow, bearing in mind the airglow observatory at Haleakala and the narrow-beam photometer now being built for Rarotonga.

The value of an ionosonde at Jarvis would be enhanced if a magnetometer could also be sited there. The addition of meteorological observations may provide data useful in New Zealand VLF studies, and the support of meterological interests should relieve the logistic position. Suggested as a temporary station with a two year occupancy.

Easter Island

Interest was expressed in a station here, mainly to fill in a large gap - permanent station. (This would not be enough by itself. In fact the same site has been proposed as a control station for numerical mapping and for other purposes.)

Adak or Unalaska

This region is roughly conjugate to New Zealand. Unalaska is the better conjugate but Adak has been running previously. Some conjugate studies have been made in the past and the opportunity should be there to do more. Permanent station.

Invercargill

1. To assist with studies of S.A.R. arcs, with special reference to the associated E region activity.

2. Near the ionospheric point for Syncom observations from Campbell Island.

3. To assist in tracking traveling ionospheric disturbances between Campbell Island and Christchurch.

Suggested as a temporary station with a two year occupancy.

Shipboard Ionosonde

It was considered desirable to have an ionosonde available for shipboard observations, e.g., directly under the crossing point of the auroral radar beams from Invercargill and Tasmania.

Note: by 1969 the Geophysical Observatory may be in the position to supply one ionosonde for both the Invercargill and shipboard observations.

3. Comments on Document (ii) Supplementing the World Network of Ionospheric Data for CCIR Purposes

Comments from those directly concerned with CCIR problems amount to saying that the CCIR documents requesting URSI aid are well founded, that the needs are real, but that the best methods of solving them should be proposed by URSI.

The views in the following quotations are also supported by a number of our consultants and probably apply with some force in particular theatres:

> "In discussions with workers on Commercial Stations I heard often, there were no interest or need for predictions, because the operators find the right frequency empirically with their instinct. So I doubt whether predictions and forecasts are of such a great need."

> "Any program must take into account the decrease of the importance of the ionospheric radio communication links (for civil use, at least)."

There is little doubt that most main long distance circuits are best controlled by their own past experience, especially where this has been properly documented and these groups have little to gain from any improvements in prediction methods. In some cases real time control could be valuable but is probably a matter for the organizations involved rather than for general scientific investigation. This is, however, a minority group, though commercially very important. When cross-examined on these points, most consultants who were concerned with the prediction business disagreed and quoted cases showing both that the operators' instincts were often misleading and that the increase in traffic tended to be faster than new techniques could cope with. There is little knowledge of these problems amongst URSI scientists not directly engaged in them. Our view is that the use of scientific methods could show where stations are most needed. In particular, the establishment of interpolation and extrapolation rules, determination of the places on the world where conditions are extreme or large gradients exist, and where monitoring stations would be most valuable are primarily scientific problems.

Interest was expressed in the proposal for new types of automatic or semi-automatic equipment. Typical comments were:

"We would like to see a special working group set up to consider these problems and promote design studies."

"We are interested in these proposals and about any equipments built as a result of them provided the price is not too high." (Several groups).

Representative particular comments on other points are as follows:

"The use of backscatter combined with satellite measures of foF2 is possible but the technique and equipment are difficult problems. Backscatter measurements of Es need careful interpretation. The CCIR Atlas needs supplementing to deal with gradients. Is it possible to prepare maps showing gradients at some height below the maximum and to devise an operational technique to correct the 'M factors' according to the slope?"

"It is important to continue OI and backscatter measurements."

"Oblique sounding measurements are not directly useful for prediction services, because the main interest of the people is to know the field strength. It is difficult from LUF observations to answer this question. Therefore, it is suggested to make cw-field strength measurements in parallel to oblique sounding. This we have already planned for the Tsumeb - Lindau path."

"It is our wish to start oblique incidence measurements in Buenos Aires. We must solve somehow first the problems derived from the high initial cost of equipment."

"We would also be interested in collaborating and/or using simplified automatic stations for forecasts, when available."

Several groups have stressed the value of backscatter and OI techniques for the study of sporadic E propagation problems. We concur.

Some consultants have asked for details of existing OI and backscatter operations, with addresses of controlling groups and there is widespread ignorance of how much satellite data is available and where it can be obtained. Clearly channels of communication do not always work and more effort is needed to advertise the facilities available.

We are aware of a number of very expensive and elaborate systems using OI soundings and other means for short time forecasts and wish to draw attention to the need to analyze the data so obtained for long term prediction and scientific purposes. There are, of course, a number of other zones where such methods could be used to advantage.

One consultant suggests a study of the North Atlantic zone:

Forecasts of Re-routing and Frequency Changes on North Atlantic Paths

To the knowledge of the author, no serious attempt has been made to design and operate a network of oblique incidences transmitting and receiving stations to determine the statistical (short and long term) optimum methods of operating HF systems on the North Atlantic for point-to-point or mobile communications. This network should provide path-loss (5 min. and 30 min.), multipath Doppler spread information, and provide a calibrated standard which could be used to design station location, routing and frequency complements and changes under a wide variety of expected conditions. It, hopefully, would provide a good estimate of the statistical capacity of HF channels on the North Atlantic for "typical" quiet and disturbed periods. The merit of the proposal is principally that we do not know this statistical capacity and arguments against further HF usage by satellite people are often based on performance which is clearly not the best we can do.

A representative comment on the relations between satellite and ground-based data is:

"Satellites cannot give information on the important structure below the maximum. There may be a need for studying ionospheric variations within one day rather than statistically. The only areas where there is a sufficiently close station network are Europe and North America. Are the station data within these areas sufficiently consistent?"

"Closer links between space programmers and ground-based stations are most desirable. Could the ground observers be given some warning of forthcoming or planned space experiments?"

Another point often made is the possible use of total electron content measurements for CCIR problems. Our view is that there is a need first for these to be collected and intercompared by scientists conversant with the technique for a scientific description of the morphology as shown by this parameter.

Summarized views on CCIR problems. Regarded as empirical exercises, the CCIR demands are for:

(a) a group of monitoring index stations
(b) continuity of operation of existing stations over a solar cycle
(c) gap-filling stations, especially in ocean areas
(d) intense study of areas where great gradients of ionization occur
(e) exploration of whether real time forecasting is feasible and can be done economically.

(a) Monitoring index stations. The CCIR requirement appears adequate for URSI needs for a similar index. It is possible to estimate whether the index is being obtained in the most economical way though this does not appear to have been done. The main weakness of IF2 is that the basic regression lines are assumed to be straight whereas a parabolic fit would be more accurate. This might give equivalent accuracy with a smaller number of sampling stations but only at the cost of developing a new index and repeating all the work of relating the index to existing operational procedures. We doubt whether the effort could be worthwhile and recommend accepting CCIR requirements for this problem.

(b) Most stations in the existing network were set up for a variety of incompatible motives, and are likely to be kept going at least as long as the data are really useful. With the possible exception of the station producing the least accurate and most incomplete data there is more than adequate scientific justification to keep most stations operating, URSI and CCIR requirements are similar.

(c) Gap filling is essentially a gamble on the ionospheric conditions being different in the gaps than could reasonably be expected. In our view prediction groups do not pay sufficient attention to scientific syntheses and scientists do not put their conclusions in a form usable (or even sometimes understandable) to practical people. We feel that at present most gap filling proposals are guesses and that a proper investigation is needed to show which are justified and which not. This is primarily the job of scientists with specialized knowledge, and the need is drawn to their attention.

(d) In this case URSI and CCIR interests are closely linked but the scientist should take the lead in showing where the greatest need lies, make the case for new work and get it supported.

(e) This is a particular facet of a new science, that of Ionospheric Meteorology, which will require relatively close nets of observations for its development. In our view new techniques should be developed for this purpose though some initial work can be done in areas where the existing network is dense, e.g., Western Europe.