SOME IONOSPHERIC RESULTS OBTAINED DURING THE INTERNATIONAL GEOPHYSICAL YEAR

PROCEEDINGS OF A SYMPOSIUM ORGANISED BY THE

URSI/AGI COMMITTEE,

AT BRUSSELS, BELGIUM, SEPTEMBER, 1959

Scientific Editor

W. J. G. BEYNON

ELSEVIER PUBLISHING COMPANY

AMSTERDAM–LONDON–NEW YORK–PRINCETON

1960

SOLE DISTRIBUTORS FOR THE UNITED STATES OF NORTH AMERICA:

D. VAN NOSTRAND COMPANY, INC.

120 Alexander Street, Princeton, N.J. (Principal office)

257 Fourth Avenue, New York 10, N.Y.

SOLE DISTRIBUTORS FOR CANADA:

D. VAN NOSTRAND COMPANY (CANADA), LTD.

25 Hollinger Road, Toronto 16

SOLE DISTRIBUTORS FOR THE BRITISH COMMONWEALTH EXCLUDING CANADA:

D. VAN NOSTRAND COMPANY, LTD.

358 Kensington High Street, London W. 14

Library of Congress Catalog Card Number 60-16513

With 266 illustrations and 24 tables

PRINTED IN THE NETHERLANDS BY

DRUKKERIJ MEIJER, WORMERVEER AND AMSTERDAM

PREFACE

The original suggestion for organising the International Geophysical Year 1957–58 (then termed the "Third International Polar Year") was brought before the Mixed Commission on the Ionosphere at its meeting in Brussels in 1950. This Commission at once prepared a memorandum elaborating the proposal and strongly commending it to the various International Scientific Unions and also to the International Council for Scientific Unions (ICSU). The International Scientific Radio Union (URSI), at its Xth General Assembly in Australia, in August, 1952, then formed a "Special Commission for the International Geophysical Year" (later known as the URSI/AGI Committee) with Sir Edward Appleton, Chairman, and Dr. W. J. G. Beynon, Secretary.

The first full meetings of this URSI/AGI Committee were held during the 1954 URSI General Assembly, and, from 1954 to 1958, it met annually to deal with all aspects of radio studies during the planning and operational phases of the IGY. The 1959 meeting of the Committee, with which this volume deals, was mainly devoted to a preliminary discussion of IGY ionospheric results. However, in this preface it is deemed appropriate to summarise briefly the main contributions of the URSI/AGI Committee to the overall IGY effort during the course of its life. Detailed reports of the 1954–58 meetings have been published in the URSI Information Bulletins. Only the principal topics which the Committee discussed are mentioned below in diary form:

1954

a. Recommendations made on the following topics: World days, tropospheric radio measurements, radio observations of the aurora, ionospheric observations (vertical soundings, absorption and drift studies), meteor observations, radio noise studies, solar radio emission, publications.

1955

a. List of IGY ionospheric stations compiled. Memorandum prepared on scaling of $h'(f)$ records.

b. Sub-Committee (Chairman: Mr. A. H. Shapley) formed to deal with all aspects of ionospheric vertical sounding (the "World Wide Soundings Sub-Committee").
c. Plans made for preparation of IGY Ionospheric Instruction Manuals.
d. Memorandum prepared on the publication of IGY ionospheric data.
e. Proposals made for IGY Regional Data Centres (later termed the World Data Centres).

1956

a. Review of world network of IGY ionospheric stations.
b. Development of proposals for Data Centres.
c. Detailed proposals for IGY absorption, drift, whistler studies.
d. Plans made for gazetteer of all ionospheric stations, with tables of solar zenith angle.
e. Plans made for preparation of an atlas of ionograms.
f. First report of the World Wide Soundings Sub-Committee covering in great detail the field of vertical soundings and including schedules, parameters to be scaled, presentation of data, interchange of data, accuracy, symbols, etc.

1957

a. Plans made for publication of "Interpretative Volumes", surveying IGY results in the radio field.
b. Proposals foı "IGY Fellowships and Studentships".

1958

a. Progress review of IGY ionospheric programme.
b. Further proposals for publication of data.
c. Plans made for preparation of ionospheric indices for the IGY Calendar Record.
d. Proposals for post-IGY ionospheric measurements.
e. Proposals for post-IGY operation of World Data Centres.
f. Plans made for a preliminary discussion of IGY ionospheric results.

The above brief recital of the tasks undertaken by the URSI/AGI Committee during the planning and operational phases of the IGY will serve to show how profound its influence on the conduct of the IGY, in radio work, has been. Undoubtedly its success has derived from the fact that the Committee, since its inception, has been composed of scientific workers who have themselves been intimately associated with the actual experimental processes of the IGY. In the same connection the Committee has been able to call on the willing cooperation of other specialists in the same fields of radio-physics.

Coming now to the work of the interpretational phase of the IGY, during which time the scientific significance of the harvest of experimentation will be sought, we may first note the magnitude of the material available for study. The fruits of the operational phase of the IGY radio programme amount to many millions of radio observations, now stored in the four World Data Centres at Washington, Moscow, Slough and Tokyo, where these are available to *bona fide* scientific workers. Further scientific progress in the way of insight and understanding will be the reward of those investigators who are able to formulate the right questions, to be answered by way of accumulated data.

It is not too fanciful, in fact, to say that, during the interpretational phase of the IGY, we are mainly concerned with "asking the data questions". The Brussels meeting of the URSI/AGI Committee, the proceedings of which are recorded in this volume, was a gathering of radio scientists from all over the world, who have been engaged in the preliminary task of "asking the data questions". It was at the same time an opportunity for the comparison of answers already obtained, and for a pooling of techniques by which questions are asked and answered.

However, although there was much progress to report, it is clear that our knowledge and understanding of many phenomena are still incomplete and we may appropriately recall a comment of the late Lord Rutherford: "This is a grand subject because there is so much in it we do not know."

E. V. APPLETON, *Chairman*

W. J. G. BEYNON, *Secretary*

CONTENTS

SECTION IV: IONOSPHERIC IRREGULARITIES

SECTION V: *N*(*h*) PROFILES

SECTION VI: ABSORPTION

SECTION VII: DRIFTS

SECTION VIII: NOISE, WHISTLERS, ROCKETS, SATELLITES

SECTION I

F2 LAYER PHENOMENA

EQUATORIAL ANOMALIES IN THE F2 LAYER OF THE IONOSPHERE

SIR EDWARD V. APPLETON

Edinburgh (Great Britain)

In this communication I deal with some of the anomalies which I have found to characterize the F2 layer in an equatorial belt centred on the earth's magnetic equator.

The latitudinal width of this belt, in round terms, is ± 20° magnetic latitude.

The identification of the geomagnetic control of the F2 layer, together with the discovery of a "trough" of low values of noon *fF2* centred on the magnetic equator[1], have necessitated some revision of F2 layer theories. For example, it is now clear that a simple world pattern of F2 layer distortion, due to semi-diurnal vertical drift of tidal origin, provides no adequate explanation of geomagnetic distortion in equatorial regions.

Perhaps our theories were formulated in advance of a full understanding of F2 layer morphology. Fortunately the vast harvest of I.G.Y. data, and especially the results from stations sited in a traverse across the geographical and magnetic equators, are likely to provide us with a fuller specification of ionospheric events which re-formulated theories will, in due course, explain.

In this paper I mention, briefly, three aspects of F2 layer morphology associated with equatorial conditions.

EQUATORIAL ANOMALIES IN N_m (F2), AS EXPRESSED BY *fF2*

In our work at Edinburgh University we have used I.G.Y. data to test the correlation of values of *fF2*, throughout the day, with (a) geographical latitude, (b) geomagnetic latitude and (c) magnetic latitude. (Magnetic latitude is, of course, directly connected with magnetic dip.) The results of this examination show that, for equatorial conditions, *fF2* is most intimately associated with magnetic latitude, or magnetic dip. This result confirms the assumption, now generally made, that the geomagnetic distortion of the F2 layer occurs ***in situ***, by way of electron transport which itself is correlated with the configuration of the earth's lines of magnetic force.

Using equatorial data for 1958, a year of sunspot maximum, plots of

References p. 7

*fF*2 with magnetic latitude, for different hours of the day, have shown that the equatorial "trough" centred on the magnetic equator is even more extensively exhibited than at sunspot minimum. Indeed the "trough" phenomenon is only absent round about 0900 h local time.

At sunspot maximum there is no trace of the evening "crest" of *fF*2 values (*e.g.* at 2100 h), associated with the magnetic equator, which occurs at sunspot minimum[2]. However, it has been found that the best way of illustrating the effect of sunspot activity on *fF*2 morphology is to plot world maps of the ***ratio*** of the values of *fF*2 at sunspot maximum and at sunspot minimum (See p. 5).

THE EVENING HEIGHT ANOMALY IN THE F LAYER

Stations within the anomalous equatorial belt centred on the magnetic equator exhibit a remarkable sequence of height changes in the F layer during the hours of local evening. This is illustrated by Fig. 1, which shows

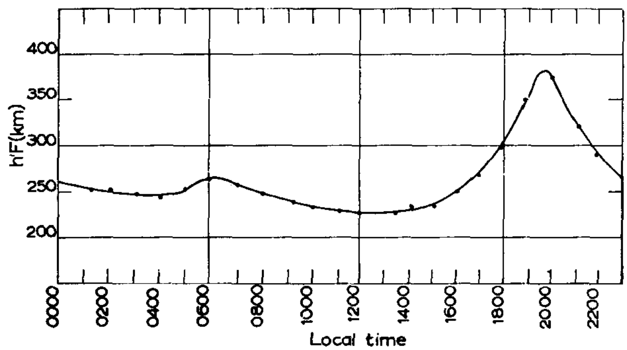

Fig. 1. Showing average diurnal variation of *h'F* for 10 stations situated within a range of magnetic latitude from 0° to ± 20°. The data refer to equinox conditions in 1958.

the average equinox diurnal variation of *h'F* for 10 stations situated within the range of magnetic latitude from 0° to ± 20°. The evening maximum of *h'F* between 2900 h and 2000 h is very striking.

In Fig. 2 there is shown, for comparison, the average diurnal variation of *h'F* for 9 stations situated between magnetic latitudes ± 20° and ± 40°, *i.e.* immediately outside the anomalous belt. It will be seen that, for these stations, there is no evidence of the evening height phenomenon in *h'F*.

An extended study of the evening height anomaly, characteristic of magnetic equatorial stations, has yielded the following results:

(a) Simultaneous studies of the diurnal trend of both h_m(F) and *h'F* show that, during the manifestation of the evening height anomaly, the

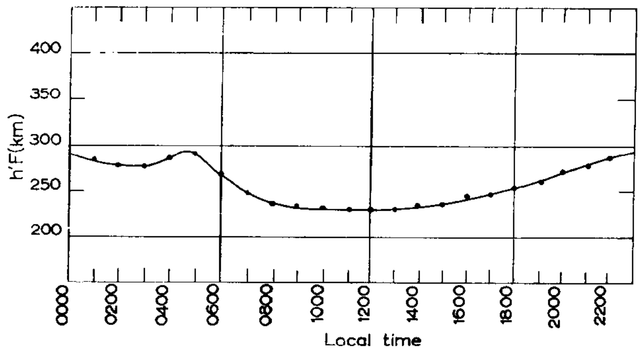

Fig. 2. Showing average diurnal variation of $h'F$ for 10 stations situated within a range of magnetic latitude from $\pm$ 20° to $\pm$ 40°. The data refer to equinox conditions in 1958.

whole F layer rises and falls. The values of h_m (F) used in this work have been derived either from $N(h)$ data or from a study of M factors.

(b) The evening height changes of $h'F$ are a maximum on the magnetic equator, and fall with increasing magnetic latitude, so that at latitudes $\pm$ 20° they are scarcely perceptible.

(c) The evening height anomaly varies very markedly with the sunspot cycle. This is evident in both h_m(F) and $h'F$ diurnal curves. For example, at Huancayo, which is situated practically on the magnetic equator, the evening peak value of $h'F$ reached at sunspot minimum was 270 km; but this increased to 390 km during the sunspot maximum period of the I.G.Y.

(d) The existence of the evening height phenomenon is possibly the explanation of certain results observed in radio communications. It has been reported by Finney, Smith, Tevten and Watts[3] that peculiar signal enhancements are observed in F layer scatter transmission during the evening hours in equatorial circuits; while Humby[4] has reported F layer refraction anomalies in short-wave radio transmission circuits which involve traversing the equatorial belt at 1900 h to 2000 h local time. Both phenomena would be explained if it were assumed that the lifting of the F layer during the evening height anomaly was associated with the introduction of electronic turmoil and irregularities in that layer.

SUNSPOT CYCLE CONTROL OF N_m (F2) AS EXPRESSED BY $fF2$

Perhaps the most striking way of exhibiting the equatorial anomaly in $fF2$ is to plot the ratio of sunspot-maximum and sunspot-minimum values of $fF2$ with magnetic latitude at different times of the day. For brevity I will call this ratio, simply, "the sunspot cycle ratio of $fF2$".

References p. 7

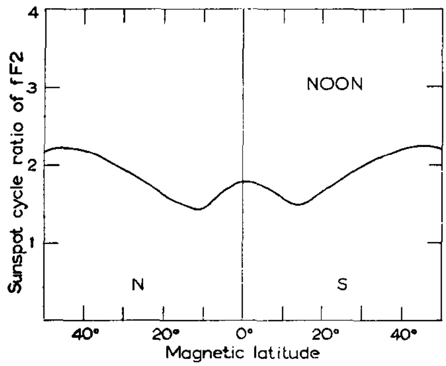

Fig. 3. Exhibiting the sunspot cycle ratio of $fF2$, for equinox noon conditions, plotted as a function of magnetic latitude.

World maps of the sunspot cycle ratio of $fF2$ (for the years 1958 (max) and 1954 (min)) show that, at the equinox, the ratio in high latitudes varies but little throughout the day from the value 2. We may infer from this that that there is little geomagnetic transport in the F2 layer in high latitudes. However, when we consider lower, and especially very low, magnetic latitudes, we find that things are quite different. In Fig. 3 there is shown a plot of the sunspot cycle ratio of $fF2$ (1958/1954) plotted as a function of magnetic latitude for noon conditions. An anomalous variation of this quantity is to be noted in the equatorial belt. However, the conditions at midnight (see Fig. 4) are even more remarkable when two striking maxima of the sunspot cycle ratio are evident at the edges of the anomalous equatorial belt. Since N_m is proportional to $(fF2)^2$ it will be noted that, at the latitudes of these

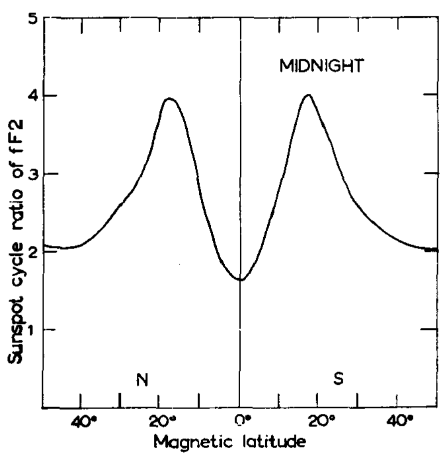

Fig. 4. Exhibiting the sunspot cycle ratio of $fF2$ for equinox midnight conditions, plotted as a function of magnetic latitude.

maxima, the value of N_m has increased 16 times due to increase of sunspot activity. By contrast the value of N_m at high latitudes has increased 4 times; while, on the magnetic equator itself, the value of N_m has increased only 2.7 times.

It is believed that phenomena of this kind cannot be wholly explained by the theory of semi-diurnal vertical drift of tidal origin. Indeed, a study of curves similar to Figs. 3 and 4 for the whole of the day, which will be published elsewhere, indicates the existence of substantial meridional transport, as first suggested by Mitra[5], in addition to vertical drift. Cogent evidence of such meridional electron transport has already been published by Rastogi[6] recently. In this connection I may mention that, in work conducted in Edinburgh, we have found an inverse correlation between noon $fF2$ at Panama and Huancayo during the I.G.Y. This is a result which might be expected according to a theory of meridional electron transport; for Huancayo is situated on the magnetic equator and Panema about 20° (in either geographic or magnetic latitude) to the north of it, on approximately the same longitude.

ACKNOWLEDGEMENT

This work has been carried out as part of the programme of the British National I.G.Y. Committee.

REFERENCES

1 E. V. Appleton, *Nature*, 159 (1946) 691.
2 E. V. Appleton, *J. Atmospheric and Terrest. Phys.*, 5 (1954) 348.
3 R. Bateman, J. W. Finney, E. K. Smith, L. V. Tevten and J. M. Watts, *J. Geophys. Research*, 64 (1959) 403.
4 A. M. Humby, *Wireless World*, July/August 1959, p. 343.
5 S. K. Mitra, *Nature*, 158 (1946) 688.
6 R. G. Rastogi, *J. Geophys. Research*, 64 (1959) 727.

SOME F LAYER PHENOMENA AT TSUMEB, SOUTH WEST AFRICA

W. DIEMINGER AND G. LANGE-HESSE
Lindau (West Germany)

PREDICTION OF F2 LAYER CRITICAL FREQUENCIES

One of the tasks of the I.G.Y. is the improvement of the predictions of radio propagation conditions, and the usefulness of a new I.G.Y. station may be judged from the difference between the values predicted from pre-I.G.Y. knowledge and the observed values. For Tsumeb ($\varphi = 19° 14'$ S, $\lambda = 17° 43'$ E) no large differences were expected because it is situated neither in the equatorial anomalous belt nor in the polar regions. The actual result of a comparison between the values predicted by D.S.I.R. and the observed ones is shown in Fig. 1. The upper curve gives the percentage of difference for the monthly medians of the mean noon values of *foF2*. The mean noon value is the average of all measurements between 1100 and 1400 h, and is representative for daylight conditions. The lower curve pertains to the monthly medians of the lowest value of *foF2* before sunrise. They, in turn, are representative for night-time conditions. The upper curve starts with a

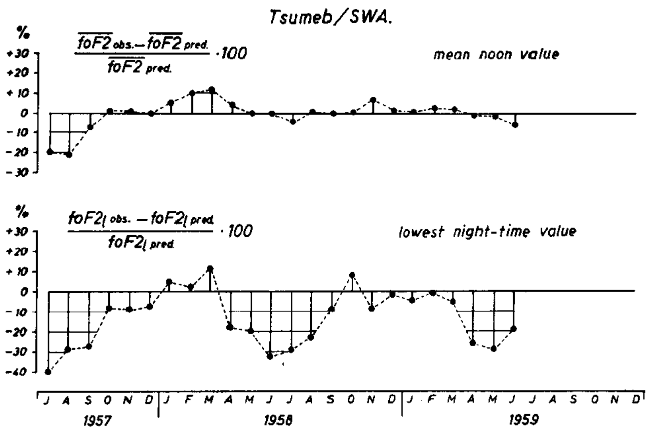

Fig. 1. Comparison between observed *foF2* values and those predicted by D.S.I.R. for Tsumeb, S.W.A.

rather large negative deviation of 20 %, *i.e.* the observed value was 20 % lower than the predicted one. The difference vanishes with approaching south summer and does not reappear in the following southern winter. The authors presume that the predictions were improved on the basis of the I.G.Y. results, which is a very satisfactory feature. The remaining curve is within the unavoidable inaccuracies. Conditions are quite different for the lower curve. It starts with the enormous negative difference of 40 % in July, 1957, which disappears in southern summer but recurs in 1958 and 1959 with nearly the same amplitude. A comparison with other stations not too far from Tsumeb yields the same large difference. There are two possible explanations: either those who make the predictions do not believe in our observations, or, more probably, they think that the lowest night-time value corresponds to a deep, but short, minimum which is irrelevant for radio propagation. This can be disproved easily. The median curve of *foF*2 for June and July, 1958 (Figs. 2 and 3) shows a shallow minimum lasting for

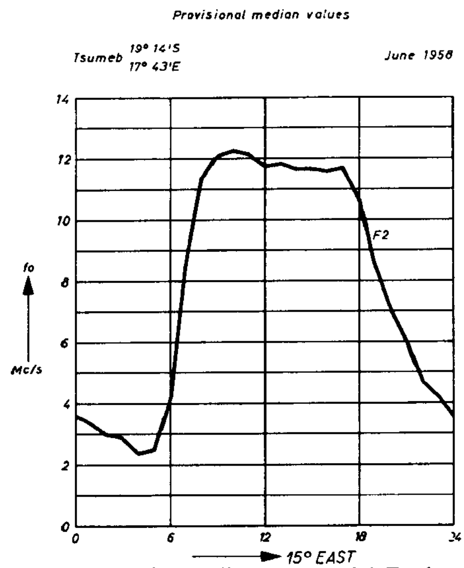

Fig. 2. Monthly median curve of *foF*2 for Tsumeb for June, 1958.

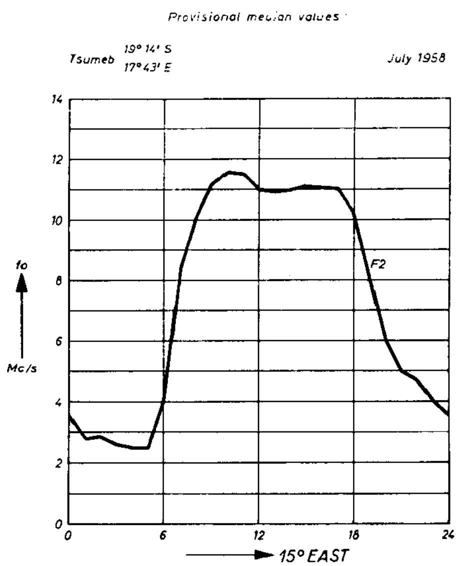

Fig. 3. Monthly median curve of *foF*2 for Tsumeb for July, 1958.

several hours. Unfortunately we cannot check the prediction next year since Tsumeb will be closed at the end of this year.

IONOSPHERIC STORMS

The influence of geomagnetic disturbances at Tsumeb corresponds closely to expectations. A comparison between Lindau and Tsumeb reveals that the

References p. 13