Gledhill, J.A., Torr, D.G. & Torr, M.R. Ionospheric disturbance and electron precipitation from the outer radiation belt. *J. geophys. Res.*, **72**, 209, 1967.

Greener, J.G. *Some properties of magnetospheric electrons observed west of Sanae*. M.Sc. thesis, Rhodes University, 1973.

Greener, J.G. & Gledhill, J.A. Electron fluxes observed near Sanae, Antarctica, by the satellite Alouette I during 1962-63. *South African Journal of Antarctic Research*, no. 2, 35-39, 1972.

Haschick, A.D. *Electron effects in the ionosphere*. M.Sc. thesis, Rhodes University, 1973.

Heikkila, W.J., Smith, J.B., Tarstrup, J. & Winningham, J.P. The soft particle spectrometer in the ISIS-I satellite. *Rev. Scient. Instrum.*, **41**, 1393, 1970.

Ivanov-Kholodny, G.S. & Kazatchevskaya, T.V. Ionization of the E-region by precipitating electrons. *J. atmos. terr. Phys.*, **33**, 285-287, 1971.

Jacchia, L.G. Revised static models of the thermosphere and exosphere with empirical temperature profiles. *Smithsonian Astrophysical Observatory, Special Report*, 332, 1971.

McDiarmid, I.B., Burrows, J.R., Budzinski, E. & Rose, D.C. Satellite measurements in the 'Starfish' artificial radiation zone. *Can. J. Phys.*, **41**, 1332, 1963.

Nicolet, M. The properties and constitution of the upper atmosphere. In *Physics of the upper atmosphere*, edited by J.A. Ratcliffe. New York and London, Academic Press, 1960.

Rees, M.H. Auroral ionization and excitation by incident energetic electrons. *Planet. Space Sci.*, **11**, 1209, 1963.

Rishbeth, H. & Garriott, O.K. *Introduction to ionospheric physics*, Sections 3.22, 3.23. New York and London, Academic Press, 1969.

Vernov, S.N., Gorchakov, E.V., Shavrin, P.I. & Sharvina, K.N. Radiation belts in the region of the South Atlantic magnetic anomaly. *Space Science Reviews*, **7**, 490, 1967.

Wilkes, M.V. A table of Chapman's grazing incidence integral Ch(x,χ). *Proc. phys. Soc.*, **B76**, 304, 1954.

Wulff, A. & Gledhill, J.A. Atmospheric ionization by precipitated electrons. *J. atmos. terr. Phys.*, **36**, 79, 1974.

(Received 5 June 1974)

The Transition between LT- and UT-controlled Behaviour of Antarctic f_oF2

M.H. Williams

Computer Science Department,
Rhodes University, Grahamstown

The rapid transition between LT-controlled and UT-controlled behaviour of f_oF2 which is observed at some Antarctic stations is studied here. The dates of transition have been determined for seven stations (six Antarctic and one sub-Antarctic) for a number of years. At the six Antarctic stations the changeover is very rapid; in addition the average changeover date for the transition from LT- to UT-control and the average changeover date for the reverse transition are symmetrical about one of the solstices. For the other station the changeover is much less sudden and the changeover dates are not symmetrical about the solstices. This may be due to a difference in the factors causing the UT peak at different stations.

Die snelle oorgang tussen LT-beheerde en UT-beheerde gedrag van f_oF2 wat by sommige Antarktiese stasies waargeneem word, word bestudeer. Die oorgangsdatums ten opsigte van sewe stasies (ses Antarkties en een Sub-Antarkties) oor 'n aantal jare is bepaal. By die ses Antarktiese stasies vind die oorgang besonder vinnig plaas; daarbenewens lê die gemiddelde oorgangsdatum vir die oorgang van LT- na UT-beheer en die gemiddelde oorgangsdatum vir die omgekeerde oorgang simmetries weerskante van een van die sonstilstande. By die ander stasie vind die oorgang veel stadiger plaas en lê die oorgangsdatums nie simmetries weerskante van die sonstilstande nie. Dit kan moontlik toegeskryf word aan 'n verskil in die faktore wat die UT-piek by die onderskeie stasies veroorsaak.

Introduction

The anomalous behaviour of the F2 region over Antarctic stations has been studied by various workers (*Duncan*, 1962; *Piggott & Shapley*, 1962; *Penndorf*, 1965). A striking feature about it is that the critical frequency of the F2 layer appears to have a "normal" LT-controlled behaviour (with maximum at about 14 hours local time) for part of the year, and a UT-controlled behaviour (in which there is a strong enhancement of f_oF2 at about 06 hours universal time) for the rest of the year.

Furthermore, the time of year when UT-controlled behaviour prevails depends on the position of the station. Stations in the area of the Weddell Sea experience LT-controlled behaviour during winter and the equinoxes and UT-controlled behaviour in summer. At stations in the Ross Sea area f_oF2 appears to be LT-controlled during the equinoxes and summer but it is enhanced at about 06 UT during winter (*Williams & Gledhill*, 1974).

A peculiar feature of this phenomenon is that at certain stations the changeover between LT-controlled and UT-controlled behaviour of f_oF2 is very sudden (see Fig. 1). This was first noticed by *Bellchambers et al.* (1962) who analysed data obtained from Halley Bay. *Piggott & Shapley* (1962) considered the changeover during the latter half of 1958 at each of five stations – Halley Bay, Ellsworth, Port Lockroy, Roi Baudouin and Byrd – and noted that the transition occurs at different dates at different stations.

This paper deals with the changeover dates observed at several Antarctic stations and one Sub-Antarctic station over a number of years. The study shows that the nature of the transition is not the same at all stations.

An Analysis of Changeover Dates

In selecting stations for this analysis, two problems were encountered. The first is that a number of stations in the Antarctic lie at longitudes in the region of 120° E; for such stations it is difficult or impossible to determine when the behaviour of f_oF2 is LT-controlled and when it is UT controlled (since 06 UT = 14 LMT at 120° E, i.e. both UT-controlled and LT-controlled peaks occur at the same time of day). The second problem was the unavailability of data from certain stations. As a result, the stations selected for this analysis were: Halley Bay, Sanae, Port Lockroy, Byrd, Ellsworth, Roi Baudouin and Campbell Island. In each case the time of day of maximum f_oF2 in summer is sufficiently different from that during winter for the transition to be easy to identify.

The dates of changeover for the above seven stations were determined for as many years as data were available. It was found that the nature of the transition at Campbell Island was noticeably different from that observed at the other stations. At Campbell Island the transition usually took place over a period of several weeks (see Fig. 2) compared with transition periods of the order of a few days for the other stations (Fig. 1). In each case the midpoint and the length of the transition period were estimated.

The dates for the transition from LT-controlled to UT-controlled behaviour are shown in Table 1 while the dates of the reverse transition are shown in Table 2. From these two tables there does not appear to be any obvious correlation between the date of transition and the sunspot cycle. In fact, the date of changeover does not appear to vary

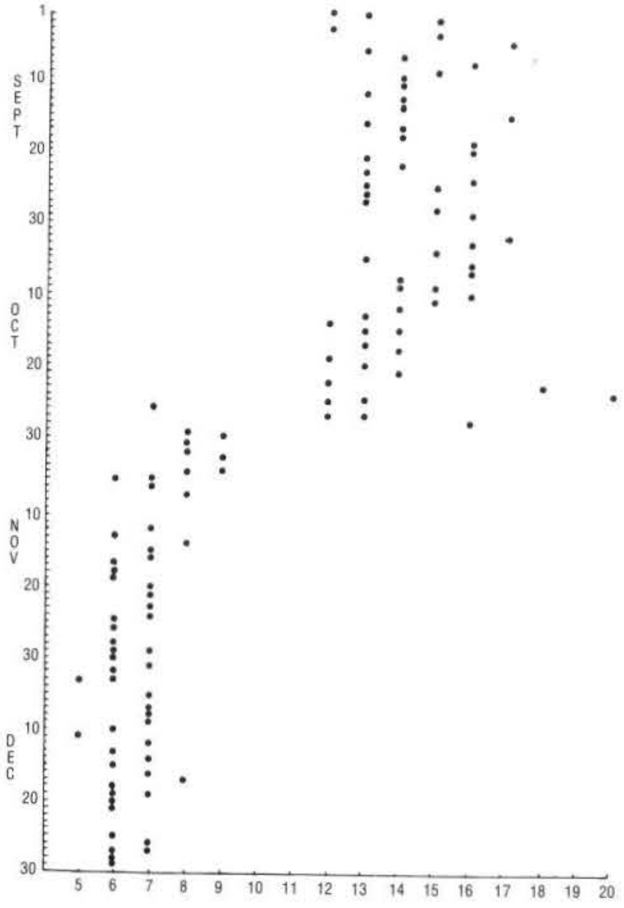

Fig. 1. Time of day of maximum f_oF2 from 1 September to 30 December 1969, showing the rapid changeover at Sanae.

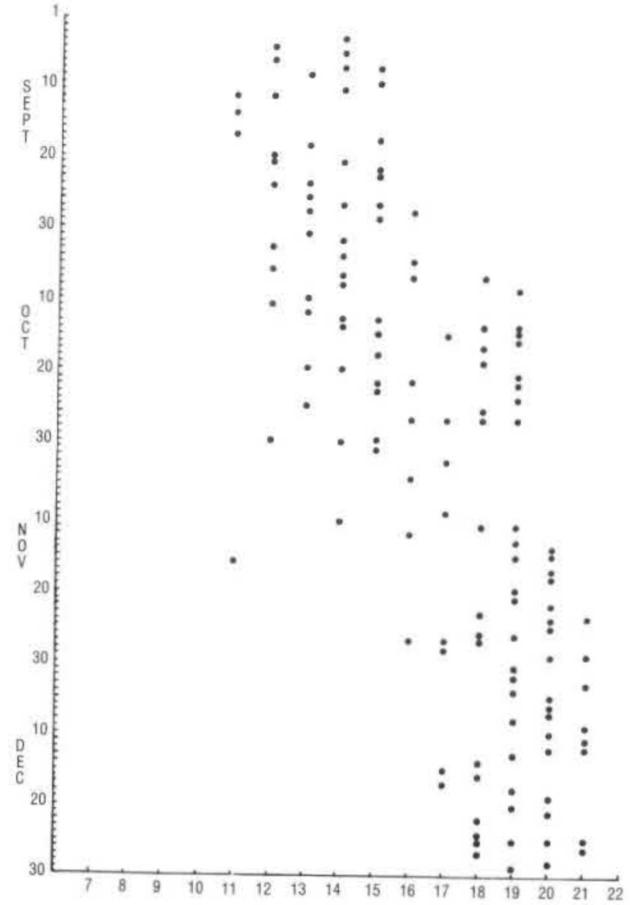

Fig. 2. Time of day of maximum f_oF2 from 1 September to 30 December 1964, showing the gradual transition at Campbell Island.

very much from year to year for stations such as Halley Bay, Sanae or Roi Baudouin.

Since there did not appear to be any obvious dependence on solar activity, the average changeover dates (averaged over all of the years for which data were available) were calculated for each station. These are shown in Table 3. This table illustrates the symmetry of the changeover dates about the solstice. In the case of Byrd the dates of changeover are noticeably symmetrical about the winter solstice. For the other six stations the UT-controlled behaviour occurs in summer. For five of these stations the changeover dates are approximately symmetrical about 22 December, while for Campbell Island they are definitely not symmetrical.

Table 1

Dates of changeover from LT-controlled to UT-controlled behaviour. These cover as much as possible of the solar cycle – sunspot maximum in 1957-58 and 1968-69 and sunspot minimum in 1964. The number in brackets gives an indication of the length of the transition period in days.

Year	Campbell Island	Sanae	Halley Bay	Port Lockroy	Byrd	Ellsworth	Roi Baudouin
1957	NOV. 25 (±5)		OCT. 16 (±1)				
1958	NOV. 10 (10)		OCT. 15 (1)		MAY 19 (±0)	OCT. 14 (±1)	OCT. 25 (±10)
1959	NOV. 10 (6)				MAY 4 (2)	OCT. 12 (4)	
1960	OCT. 24 (12)		OCT. 12 (1)		MAY 6 (4)	OCT. 15 (4)	
1961	NOV. 1 (15)		OCT. 7 (1)		MAY 6 (3)	OCT. 9 (3)	
1962	OCT. 15 (11)	OCT. 26 (±2)		OCT. 2 (±2)		OCT. 10 (5)	
1963	OCT. 27 (15)						
1964	OCT. 29 (15)	OCT. 26 (0)	OCT. 11 (1)	OCT. 5 (0)			OCT. 28 (1)
1965	OCT. 30 (11)		OCT. 11 (1)	OCT. 14 (1)			OCT. 30 (1)
1966	OCT. 14 (5)	OCT. 25 (0)	OCT. 16 (1)	OCT. 23 (1)			OCT. 25 (1)
1967		OCT. 21 (1)	OCT. 15 (1)	OCT. 22 (2)			
1968		OCT. 21 (1)	OCT. 17 (3)	OCT. 13 (0)			
1969		OCT. 26 (1)		OCT. 21 (6)			
1970			OCT. 11 (1)	OCT. 25 (3)			

Table 2

Dates of changeover from UT-controlled to LT-controlled behaviour

Year	Campbell Island	Sanae	Halley Bay	Port Lockroy	Byrd	Ellsworth	Roi Baudouin
1957					JUL. 27 (±1)		
1958			MAR. 7 (±3)		JUL. 28 (4)	MAR. 3 (±0)	
1959	MAR. 11 (±5)				AUG. 3 (2)		
1960	MAR. 19 (8)				JUL. 28 (2)	MAR. 9 (8)	
1961	MAR. 18 (12)		MAR. 15 (1)		AUG. 11 (2)	MAR. 12 (2)	
1962	MAR. 24 (18)					MAR. 11 (5)	
1963	FEB. 28 (10)	FEB. 20 (±1)	MAR. 10 (3)	MAR. 12 (±1)			
1964	MAR. 13 (14)	FEB. 26 (2)		MAR. 17 (0)			
1965	MAR. 19 (12)		MAR. 9 (1)	MAR. 13 (1)			FEB. 26 (±2)
1966	MAR. 12 (7)	FEB. 20 (0)					FEB. 26 (3)
1967		FEB. 21 (1)	MAR. 9 (1)	FEB. 25 (2)			
1968		FEB. 28 (1)		MAR. 9 (0)			
1969		FEB. 25 (1)	MAR. 10 (2)	FEB. 22 (1)			
1970				MAR. 8 (1)			

These average changeover dates were plotted against geographic latitude, geomagnetic latitude and L-value but in each case no reasonable correlation was apparent.

Discussion

The most significant results obtained from the above analysis are thus:

(i) The transition between LT-controlled and UT-controlled behaviour occurs over a period of several weeks at Campbell Island, but at the other six stations it takes place over a few days.

(ii) The changeover dates at the six stations Sanae, Halley Bay, Port Lockroy, Ellsworth, Roi Baudouin and Byrd display definite symmetry about the solstices while changeover dates at Campbell Island are not symmetrical in this way.

In order to explain these differences in the changeover process, one must first establish the cause of UT-controlled behaviour. *King et al.* (1971) have shown, by solving the continuity equation with a wind term included, that winds can account for an enhancement of the critical frequency of the F2 region at about 06UT at Antarctic and Sub-Antarctic stations. However, while their solutions correctly predict a strong UT enhancement in summer for stations in the Weddell Sea area, they do not account for the fact that stations in the Ross Sea area experience the UT enhancement more strongly in winter than in summer (*Williams & Gledhill*, 1974). To explain this (and the high values of f_oF2 observed at Ross Sea stations during winter), it has been suggested that particle precipitation may occur during winter, and that this is redistributed by the winds (*King et al.*, 1971). Certainly particle precipitation is thought to play an important role in maintaining the Antarctic ionosphere (*Thomas & Andrews*, 1969; *Pike*, 1970).

It has been suggested (P.J. Harvey, private communication, 1964) that at some stations both peaks are evident in the data for most of the year but that one is usually much larger than the other. During the transition from LT-control to UT-control, the amplitude of the 06 UT peak

Table 3

The average changeover dates for the transition between UT- and LT-controlled behaviour at seven Antarctic and Sub-Antarctic stations

Station	LT to UT transition		UT to LT transition	
	Date	No. of days before Dec. 22	Date	No. of days after Dec. 22
Ellsworth	OCT. 12	71	MAR. 9	77
Halley Bay	OCT. 13	70	MAR. 10	78
Port Lockroy	OCT. 16	67	MAR. 7	75
Sanae	OCT. 24	59	FEB. 23	63
Roi Baudouin	OCT. 27	56	FEB. 26	66
Campbell Island	NOV. 1	51	MAR. 14	82

Station	LT to UT transition		UT to LT transition	
	Date	No. of days before June 21	Date	No. of days after June 21
Byrd	MAY 9	43	AUG. 1	41

rises so rapidly that, despite fluctuations in the two peaks, the transition takes only a few days. Similarly the transition from UT-control to LT-control is due to a rapid diminution of the UT peak.

Certainly this theory does appear to explain the rapid changeover observed at the six Antarctic stations but not the behaviour at Campbell Island. One possible reason for this may be that the UT peak observed at Campbell Island is purely a wind effect (since it may be too far north to receive sufficient particle precipitation and, in addition, the height of mirror points is at a maximum for the L = 4 L-shell in the vicinity of Campbell Island) while that observed at the other six stations is caused by a combination of winds and particles. Since winds are caused by pressure differences due to differences in temperature and since exospheric temperatures are not symmetrical about the solstices, this may explain why the changeover dates at Campbell Island are not symmetrical about the solstices. Particle precipitation, on the other hand, may depend on the configuration of the Earth's magnetic field, which would tend to be symmetrical about the solstices. However, in order to verify this a detailed analysis of particle precipitation belts is required together with more reliable wind measurements.

Acknowledgements

This work forms part of the Antarctic ionosphere research programme at Rhodes University, and the support of the Department of Transport is gratefully acknowledged. I should also like to thank Professor J.A. Gledhill for reading the manuscript and providing useful comments.

The Editor acknowledges the assistance of Professor W.J. Ross of the College of Engineering, Pennsylvania State University, and another referee in evaluating this paper.

References

Bellchambers, W.H., Barclay, L.W. & Piggott, W.R. *The Royal Society IGY Antarctic Expedition, Halley Bay 1955-1959*. London, The Royal Society, 1962.

Duncan, R.A. Universal-time control of the Arctic and Antarctic F-region. *J. geophys. Res.*, **67,** 1823-1830, 1962.

King, J.W., Eccles, D. & Kohl, H. The behaviour of the Antarctic ionosphere. *J. atmos. terr. Phys.*, **33,** 1067-1077, 1971.

Penndorf, R. Geomagnetism and aeronomy. *Antarctic Research Series*, **4,** 1-45. American Geophysical Union, 1965.

Piggott, W.R. & Shapley, A.H. *Antarctic Research Geophysical Monograph*, no. 7, 111-126. American Geophysical Union, 1962.

Pike, C.P. Universal time control of the South Polar F layer during the IGY. *J. geophys. Res.*, **75,** 4871-4876, 1970

Thomas, J.O. & Andrews, M.K. The Trans-Polar exospheric plasma. 3. A unified picture. *Planet. Space Sci.*, **17,** 433-446, 1969.

Williams, M.H. & Gledhill, J.A. F2 critical frequencies at pairs of Antarctic stations at the same latitude. *J. atmos. terr. Phys.*, **36,** 647-655, 1974.

(Received 18 April 1974)

Methods of scaling Whistlers in the Absence of the Initiating Sferic and Nose Frequency

A.D.M. Walker
and
K.F. Deane

Department of Physics,
University of Natal, Durban

Four methods of scaling whistler sonagrams in the absence of initiating sferic and nose are compared. It is concluded that, while all give acceptable results, the method of *Ho & Bernard* (1973) is most economical of computer time and scaling time.

Vier metodes om sonagramme van fluiters in afwesigheid van inisiërende sferieksteuring en neusfrekwensie te skaleer, word vergelyk. Alhoewel met al die metodes aanvaarbare resultate verkry word, blyk die metode van Ho & Bernard *(1973) wat rekenaartyd en skaleertyd betref die voordeligste te wees.*

Introduction

Whistler sonagrams are commonly used in order to obtain information about the electron density in the plasmasphere (*Helliwell*, 1965). If a suitable model is assumed, a knowledge of the nose frequency and position of the initiating sferic for each whistler trace allows the L value of the duct in which the whistler has propagated, and the electron density distribution in the duct to be deduced (*Park*, 1972). Frequently both initiating sferic and nose are absent on the trace and recently there has been great interest in curve-fitting techniques for deducing the position of the sferic and the nose frequency (*Rycroft & Mathur*, 1973; *Ho & Bernard*, 1973). These are based on one of two fitting formulae (*Dowden & Allcock*, 1971; *Bernard*, 1973).

In this paper four methods of deducing the nose frequency and sferic position are discussed and compared. The methods are tested on synthetic data computed from a model plasmasphere. All methods give similar results and the choice of method is a matter of convenience. It is concluded that the most economical of computer time and manpower is that of *Ho & Bernard* (1973) with a modification which makes more efficient use of the data available. This method is now in use for scaling data from Sanae, Antarctica.

The whistler group delay and plasmasphere models

Whistlers which have travelled in ducts in the plasmasphere have a time delay which is frequency dependent. The expression for the delay, τ, is (*Helliwell*, 1965, p. 182)

$$\tau = 2c\, f^{-1/2} \int_{\text{path}} \frac{f_N f_H}{(f_H - f)^{3/2}}\, ds \tag{1}$$

where f is the wave frequency, f_N the plasma frequency, f_H the electron gyrofrequency and c the free space speed of light. The integral is taken along the path, with ds the element of path length. The quantities f_N and f_H are functions of s. The dispersion $D = \tau\sqrt{f}$, is a parameter frequently used.

In standard methods of data reduction approximations are made to this law and whistler traces are analysed on the basis of assumed models. It is normally assumed that the earth's magnetic field is that of a centred dipole and that the plasmasphere is in ambipolar diffusive equilibrium, with ions and electrons constrained to move along the magnetic field lines (*Angerami & Thomas*, 1964).

In this paper synthetic whistlers have been computed from equation (1) by evaluating the integral using Simpson's rule. These have then been scaled by different techniques, and the results compared. The model used was that of *Rycroft & Alexander* (1969) for winter night. It is a diffusive equilibrium model which is representative of average conditions in the plasmasphere. It is assumed that a duct exists at intervals of 0,5 in L between L = 2,5 and L = 6. Some of the resulting synthetic whistlers are shown in Fig. 1 and may be compared with a typical sonagram from Sanae shown in Fig. 2.

Fitting formulae for the whistler group delay

The formula of Dowden & Allcock

On empirical grounds *Dowden & Allcock* (1971) have proposed that Q, the reciprocal of the dispersion, is linear in f. This leads to an expression for delay of the form

$$\tau = \tau_0 + \frac{1}{\sqrt{f}}\,\frac{D_0}{1 - f/af_n} \tag{2}$$

or

$$Q\,(\equiv (\tau - \tau_0)\sqrt{f}) = \frac{1}{D_0}\,(1 - f/af_n) \tag{3}$$