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Structural Changes in Ionosonde E_S over Three Solar Cycles

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Abstract

A survey over 37 years of the ionization structure of temperate latitude daytime sporadic-E, inferred from ionogram characteristics, shows a close association between solar cycle and the type of structure. Sporadic-E demonstrates a high degree of scattering near sunspot minimum.

1. Introduction

Ground-based swept-frequency soundings of the ionosphere are an established technique valuable in morphological studies. Such ionosonde sampling at hourly intervals is unable to provide detailed probing of highly structured regions but is useful in providing long-term data for synoptic studies. An area where ionosonde probes are valuable is in observations of one form of irregularity found within the E region. Sporadic-E (E_s), unlike the regular ionospheric regions, is quasi-random in occurrence and has diverse structure (From 1983). The ionization structure of an E_s layer is seen on an ionogram as a partial transparency: $f_b E_s$ is the ionosonde frequency below which blanketing of higher regions is complete and $f_o E_s$ is the top penetration frequency when the ordinary propagation mode is resolved; the layer is partially transparent in the frequency regime between these limits. It is generally agreed that this feature results from scattering by a region that consists of small scale enhanced plasma concentrations embedded in ambient ionization. Rocket and incoherent backscatter studies indicate that $f_o E_s$ corresponds to the peak value of plasma frequency in the enhanced small scale irregularities within the layer, while $f_b E_s$ is representative of the lowest value (Reddy and Mukunda Rao 1968; Smith and Mechtly 1972; Miller and Smith 1978). From (1983) has delineated the types of blanketing and non-blanketing E_s clouds and described the horizontal structure and ionization compression in terms of the superposition of internal gravity waves.

Since the scattering properties of an E_s layer are reflected in the difference between $f_o E_s$ and $f_b E_s$, it is interesting to ask whether this difference is dependent on the concentration of the background E-region ionization. Are the scattering properties of E_s clouds and hence transparency characteristics of ionogram E_s traces associated with solar cycle? The present paper examines the transparency characteristics of daytime E_s clouds as depicted by the differences between $f_o E_s$ and $f_b E_s$ over an extended period of three solar cycles.

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2. Analysis

A small difference between ionogram traces $f_o E_s$ and $f_b E_s$ is indicative that scattering is weak in the E_s cloud being probed, while a large difference is evidence of a large scattering component produced by a large population of small scale plasma concentrations having a broad spectrum of plasma densities.

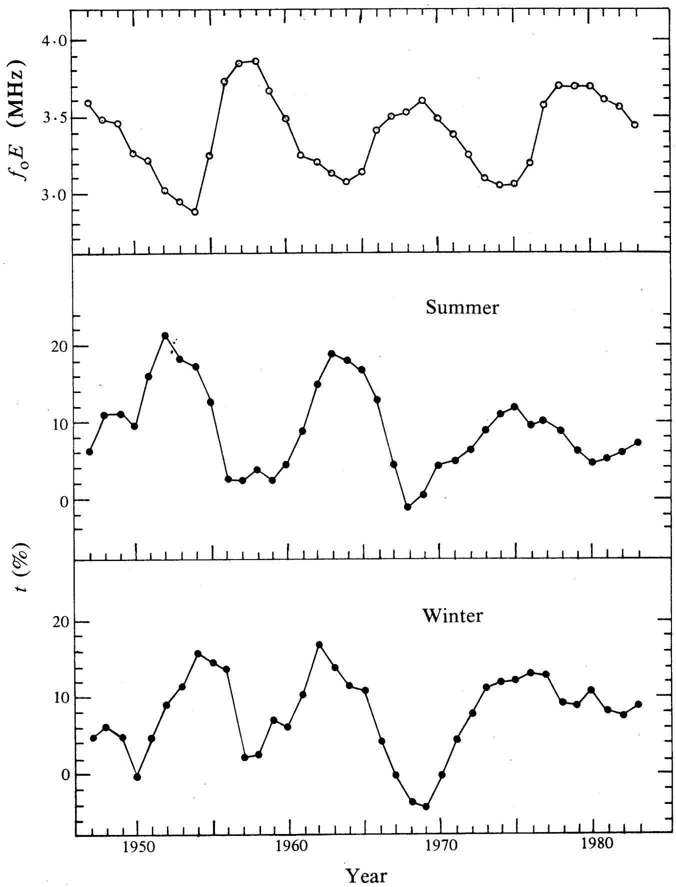

Fig. 1. Variation of the transparency factor t from 1947 to 1983 for daytime E_s summer and winter for Christchurch. Also shown are the running mean values of midday $f_o E$ for Christchurch (see Section 2).

We write the ratio of the difference between $f_o E_s$ and $f_b E_s$ to their mean, expressed as a percentage, as the transparency factor t:

$$t = 200(f_o E_s - f_b E_s)/(f_o E_s + f_b E_s),$$

which provides a measure of the transparency condition. In an attempt to delineate any long-term solar cycle control, a survey was carried out of the monthly median values of $f_o E_s$ and $f_b E_s$ for the Southern Hemisphere temperate latitude station Christchurch ($-43°\cdot 5$, $172°\cdot 5$). Temperate zone sporadic-E exhibits a major maximum of occurrence in local summer and a secondary enhancement in winter. Daytime occurrence, defined by the five hourly values 10–14 LMT, was examined and the mean of the median values calculated for two 2-month periods each year: December and January (summer), and June and July (winter). Each year's summer and winter data contained, therefore, a possible 310 values.

The change in the transparency factor between 1947 and 1983 is shown in Fig. 1 and compared with the 12-month running mean values of the monthly averages of the median $f_o E$ values 10–14 LMT. The transparency values were plotted by using a 3-point (1,2,1) weighting for ease of interpretation. The analysis reveals quite clearly that the transparency factor changes in anti-phase with long-term variations of $f_o E$ under solar cycle control. The E_s clouds are opaque up to the top penetration frequency at epochs when $f_o E$ is high near sunspot maxima, in contrast to significant scattering near sunspot minimum with $f_o E_s$ exceeding $f_b E_s$ by up to 25%. There are cases near sunspot maxima when the factor is negative, implying that $f_b E_s$ exceeds $f_o E_s$: this anomalous result is produced on those few occasions when only a few entries are published for $f_b E_s$, so that the median value of midday $f_b E_s$ is a rather uncertain estimate.

3. Conclusions

This analysis has revealed a close association between the transparency shown by daytime E_s ionogram traces in both winter and summer with E-region plasma frequency over three solar cycles. This increase of $f_b E_s$ with increasing background peak electron density, as indicated by $f_o E$ over a long term, is clearly relevant to theories of the mechanisms involved in E_s production. Complete blanketing is featured near sunspot maxima, while at sunspot minima, E_s layers can be transparent to low probing frequencies. This behaviour is in accord with the finding that daytime cumulative occurrence of medium frequency $f_b E_s$ events is in phase with solar cycle (Reddy and Matsushita 1968; Baggaley 1984). The behaviour suggests that irregular layers containing an assembly of plasma scattering concentrations are characteristic of sunspot minimum conditions, while more uniform layers with an absence of scattering at high frequencies are associated with sunspot maxima. Changes in the ionization structure of E_s clouds depend on solar cycle; these structural changes might arise, for example, from a changing pattern of internal gravity waves which may be responsible for plasma compression (From 1983).

References

Baggaley, W. J. (1984). *J. Atmos. Terr. Phys.* **46**, 207.
From, W. R. (1983). *Plan. Space Sci.* **31**, 1397.
Miller, K. L., and Smith, L. G. (1978). *J. Geophys. Res.* A **83**, 3761.
Reddy, C. A., and Matsushita, S. (1968). *J. Geophys. Res.* **73**, 1641.
Reddy, C. A., and Mukunda Rao, M. (1968). *J. Geophys. Res.* **73**, 215.
Smith, L. G., and Mechtly, E. A. (1972). *Radio Sci.* **7**, 367.

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