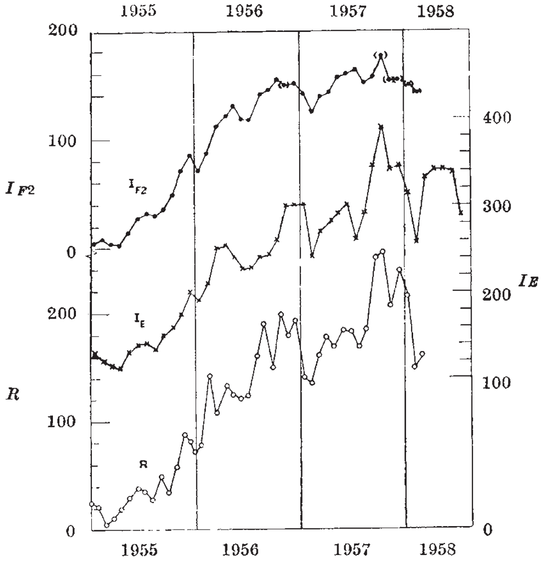


Fig. 1. The behaviour of the present sunspot cycle as indicated by the sunspot number and two ionospheric indices. ●—●—●, ionospheric index, $I_{F2}$ [( ) doubtful value] ; ×—×—×, ionospheric index, $I_E$ ; ○—○—○, rotational mean sunspot number $R$ (after Visser)

of these indices are shown in Fig. 1 for the period January 1955 to date, together with the rotational mean values of the sunspot number taken from Visser's diagram. Both the ionospheric indices and the sunspot numbers vary in a very similar way, and even the smaller irregularities in the trend are sometimes visible in all three curves.

Visser also refers to the secondary oscillations in the sunspot number which occurred during the period 1947–50. These oscillations can also be clearly seen in even the unsmoothed values of the index $I_{F2}$ for this period, and there is some evidence for their existence in the years following the 1938 peak in solar activity[3]. It is important to remember that, although ionospheric ionization is subject to large seasonal changes, there is no significant annual component in the indices $I_E$ and $I_{F2}$. Hence, the fact that, at the epochs mentioned above, the oscillations in the ionospheric indices have a period of roughly one year cannot be attributed to a residual seasonal component in these indices.

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[1] Visser, S. W., *Nature*, **182**, 253 (1958).
[2] Minnis, C. M., and Bazzard, G. H., *J. Atmos. Terr. Phys.* (in the press).
[3] Minnis, C. M., *J. Atmos. Terr. Phys.*, **7**, 310 (1955).

Mr. C. M. Minnis's communication elucidates matters considerably.

The "unspecified ionospheric index" is that determined at De Bilt (daily sums of eight 3-hr. data).

At first I used the $f_0F2$ data of Slough and Washington[1,2], but since the data from De Bilt coincided fairly well with those of $f_0F2$ at Washington (ref. 2, Fig. 8) I therefore left the Slough and Washington data and took those of De Bilt, which were directly at my disposal. I must agree now that, for the present purpose, the simple $I$ index of De Bilt does not suffice. As regards the secondary peaks, I find that their period certainly does not have a duration of about one year. I have now completed the investigation from 1863 to date. All sunspot cycles, Nos. 11–19, show the same character with considerable secondary peaks. A broad scattering from 6 to 19 synodic rotations being present, it is evident that there is no question of a regular period. Yet this feature of the sunspots may point to some interesting secondary solar action.

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[1] Visser, S. W., *Sci. Proc. Int. Assoc. Met.*, Tenth Gen. Assembly, Rome, 271, point 7 (1954).
[2] Visser, S. W., *Trans. Amer. Geophys. Union*, **39**, 835 (1958).

## Maxwell Fish-eye treated by Maxwell Equations

The so-called Maxwell fish-eye[1] is a non-homogeneous lens the index of refraction of which varies according to the relation :

$$n(r) = \frac{2}{1 + (r/R)^2} \qquad (1)$$

where $R$ denotes the radius of the sphere, and $r$ the radial distance measured from the centre of the sphere. If a point source is located at the rim of the sphere the lens will focus the rays to another point on the rim at the opposite side. The lens was invented by James Clerk Maxwell in 1860 based upon the method of geometrical optics. It was the year before his enunciation of the electromagnetic theory of light.

In a previous communication[2] the problem of the Luneberg lens was treated rigorously as a boundary-value problem within the framework of the Maxwell equations. It was indicated therein that the same technique can be used to investigate the Maxwell fish-eye. The core of all such radially stratified problems is to resolve two differential equations of the form :

$$\frac{d^2S_n}{dr^2} + \left[k^2\varkappa(r) - \frac{n(n+1)}{r^2}\right]S_n = 0 \qquad (2)$$

and

$$\frac{d^2T_n}{dr^2} - \frac{d\varkappa(r)}{\varkappa(r)dr}\frac{dT_n}{dr} + \left[k^2\varkappa(r) - \frac{n(n+1)}{r^2}\right]T_n = 0 \quad (3)$$

where $k = \frac{2\pi}{\lambda}$ is the wave-number and $\varkappa(r) = n^2(r)$.

The constant $n$ in these two equations is an integer. The two functions $S_n$ and $T_n$ are associated, respectively, with the transverse electric and the transverse magnetic modes in the analysis of the problem.

For the Maxwell fish-eye, if one substitutes equation (1) into equations (2) and (3) the resultant differential equations can be reduced to the hypergeometric equation by two transformations. Thus, if one denotes :

$$\rho = kr, \text{ and } \rho_0 = kR$$

then by changing the independent variable to $\xi$ defined by :

$$\xi = -\rho^2/\rho_0^2$$