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Electron Density in the South Atlantic Anomaly Region

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Abstract. Since an increased particle flux was found in a well-defined region in the South Atlantic, AEROS-B electron density measurements of August 1974 were checked for a similar effect. During daylight no particular influence could be found, for quiet as well as for disturbed conditions. During night the Atlantic longitude sector shows greater electron densities, but there is no well-defined disturbance area as found for the particle flux.

Key words: Ionosphere – South atlantic anomaly.

The aeronomy satellites Aeros-A and -B were both Sun-synchronous in polar orbits covering a height range between about 220 and 800 km (Lämmerzahl and Bauer, 1974). The instrumentation comprised an EUV-spectrometer, a retarding potential analyzer and an impedance probe, both for plasma diagnostics, and two mass-spectrometers, one of which analyzed natural ions and neutrals alternatively. On the night side the EUV spectrometer recorded keV electrons. A remarkable increase of this corpuscular radiation was found to occur in the South-Atlantic, centered at about 30° S, 320° E (Knoll et al., 1977). The extension of this phenomenon was approximately by 15° in latitude and 30° in longitude on either side.

Since there are no ionosonde stations in this oceanic region, we found it worthwhile to look for corresponding features of the thermal plasma population in the data obtained in August 1974 with the impedance probe (Neske and Kist, 1974) aboard the satellite Aeros-B. At low and middle latitudes the local time at the satellite was almost constant at 3h30 on the night side and 15h30 at the day side. To show typical results for day time we present days no 213 (1 August) and 215 (3 August). 1 August was magnetically quiet with Kp-values 1 and 2. A sudden commencement occurred at noon UT on 2 August starting a magnetic disturbance which reached its maximum ($Kp = 6^+$) at the end of 3 August. Thus day 215 was during a developing disturbance.

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Since the upper ionosphere has a longitude effect, mainly due to the magnetic field, the question arises with which latitudes the South-Atlantic data should be compared at other longitudes. The same problem occurred in the past when world-wide mapping of the peak electron density was asked for. In 1967, to this end, the Comité Consultatif International des Radiocommunications (C.C.I.R.) adopted a particular coordinate proposed by Rawer (1963). This "modified dip" coordinate (abbreviated to "modip" μ) is defined by

$$\tan \mu = I/\sqrt{\cos \varphi}$$

where φ is geographic latitude and I magnetic inclination (as measured in radians): Modip essentially equals dip in the equatorial region but comes to geographic latitude near the (geographic) poles.

Using this coordinate let us first consider the sunlit hemisphere, around 15h30 LT. Figures 1 and 2 show the electron density curves measured during different satellite passes. The general density increase towards North is due to the satellite orbit: On these days the apogee was between 72° and 76° S (geographic) so that the perigee occurred on the night hemisphere at high northern latitude. In the range presented in both Figures the satellite was going down towards the peak altitude of the ionosphere, which was reached around 80° N (geographic). The curves of Figs. 1 and 2 are therefore oblique cuts in height and latitude (modip).

In order to correct for the effect of variable satellite height, we should transform the measured data to a fixed altitude. This can be done with a standard profile as reference. We took as such a model established (mainly with ALOUETTE data) by Bent and Llewellyn (1970), which uses as independent variables; magnetic latitude, solar activity, but also peak density and altitude, these latter being deduced from the C.C.I.R. numerical maps. Taking the relative change with height from the model, observed densities at a given altitude can be transformed to another altitude (Noor Sheikh et al., 1978). In such a way, Fig. 3 was obtained from Fig. 1 for an altitude of 700 km, in the modip angle range −40° to −20° (where the South Atlantic anomaly occurs). No important differences in electron density are seen between the different passes except that pass 247 at longitude 262 E has the steepest gradient. Pass 244 which had a longitude of 333°, just in the anomaly, shows no particularity. Thus, a remarkable anomaly effect on the electron density does not occur during a quiet day.

On the disturbed day 215 we meet a totally different situation. Figure 2 shows that depending on the development of the disturbance, there was a drastic increase of electron density in the equatorial belt (so-called positive perturbation). This increase was, however, not seen at all longitudes, only in the far East (145° and 97°) and in Europe/Africa (2°), not in the near East (49°) and in the Atlantic (315°). This could reveal a development in time of the disturbance, but it is also known that increased ionization can occur in isolated longitudinal shells. In any case there is no specific effect occurring at Atlantic longitudes only.

We conclude that no appreciable anomaly effect could be found in daytime, neither for quiet nor for disturbed conditions.

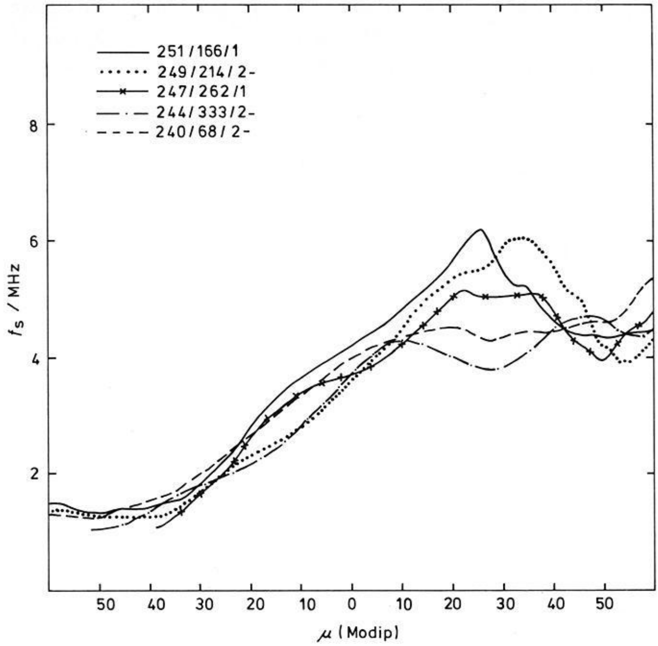

Fig. 1. Local plasma frequency fs (proportional to square root of electron density) as measured during daytime at the satellite, as a function of the "modified dip angle" μ (given in degrees, abbreviated by "Modip"; for explanation see text). Day 213, 1974 – quiet. Parameters: orbit no./nod longitude/Kp value

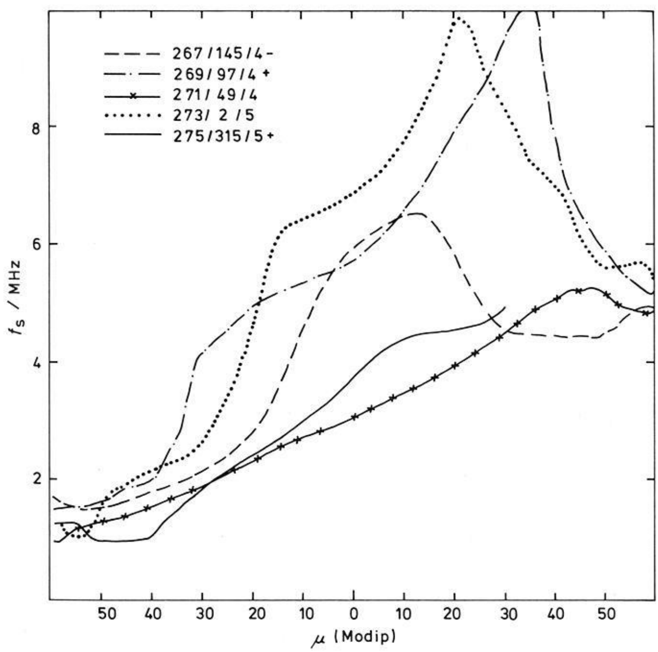

Fig. 2. Same as Fig. 1, but Day 215, 1974 – disturbed

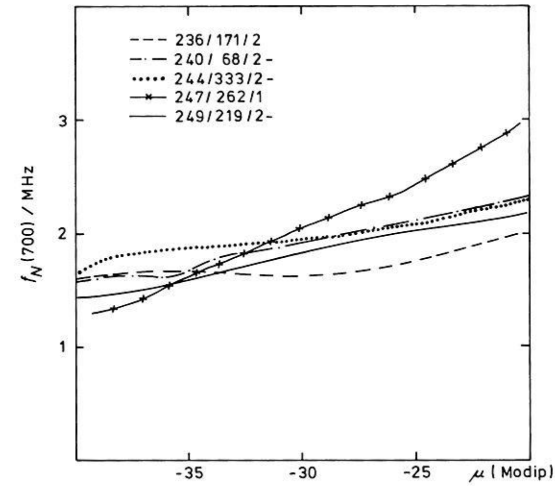

Fig. 3. Virtual plasma frequency during daytime at 700 km (above the South Atlantic) deduced from in situ measurements. Day: 213, 1974 – quiet

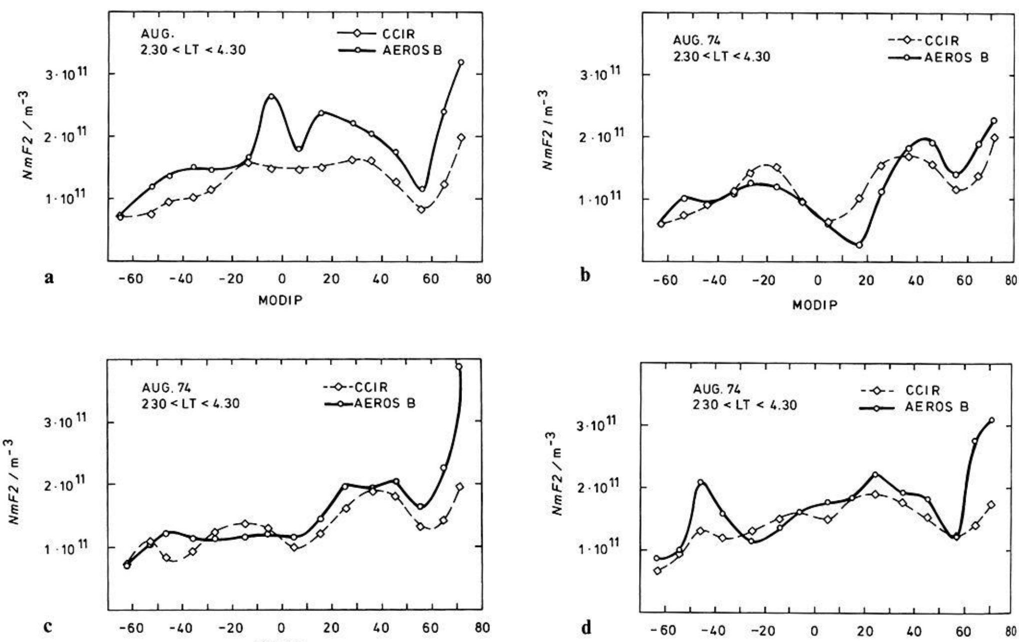

Fig. 4a–d. Peak electron densities (*full curves*) deduced from Aeros-B measurements (averages for August, 1974), at night, for the following selected longitude ranges: **a** America, **b** Atlantic, **c** Eurasia, **d** Pacific. *Broken curves:* C.C.I.R. prediction for comparison

At night the satellite was slightly above peak altitude in the South Atlantic zone. After reduction to peak altitude our data allowed to establish typical monthly median variations for different longitude ranges. Modip was again used as coordinate in Fig. 4. The absolute density values are highest in the American longitude zone, but it is difficult to identify a particular effect in the South Atlantic. An interesting point is the bifurcation near the dip equator, which is a typical low latitude day-time phenomenon. This occurs only at American longitudes as reported by Knudsen and Sharp (1968). The phenomenon might be related with the excentricity of the terrestrial magnetic field but, if so, is not centered in the South Atlantic but more a general feature of this longitude.

Discussions and Conclusions

Gledhill (1976) has summarized electron density measurements in the anomalous region. Some workers find a minimum and others a maximum at the location of the lowest magnetic field intensity on a given L-shell. As a possible explanation, two competing processes were proposed, namely ionization by the precipitated electrons tending to increase foF2 and heating of the atmosphere tending to reduce it by increased recombination. Our measurements show no remarkable enhancement in the South Atlantic region at altitudes around 700 km during daytime. At somewhat lower altitudes at night the American longitude zone has increased electron density, without a particular enhancement above the Southern Atlantic. It may be that the idea of a "conjugate F-region enhancement" (Pike et al., 1968) could give an explanation. At any case the well-defined zone of the corpuscular anomaly (Knoll et al., 1977) is not privileged in electron density.

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