F1.5/F3 Layers in the Equatorial Ionosphere

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Introduction

Recent theoretical work has established an explanation for an ionospheric phenomenon seen only at low latitudes and reported intermittently for over 50 years. This is the stratification of the F2 layer occurring in daytime, usually at sites displaced from the magnetic equator, but within the region covered by the equatorial anomaly. Reported observations in the literature, often in very old references (e.g. Sen, 1949), have been too easily dismissed as due to traveling ionospheric disturbances. The closure of most of the low latitude ionosonde sites of yesteryear has allowed this gap in our understanding of the low latitude ionosphere to continue until a confluence of theory (the SUPIM model) and observation (initially at Fortaleza, Brazil) was achieved (e.g. Balan et al., 1997, 1998 and Jenkins et al., 1997).

In recent times, a number of vertical and oblique ionosondes have been operating from Australia as well as within the area covered by the southern equatorial anomaly. These observations clearly show the existence of the F2 stratification as a regular rather than an anomalous phenomena and have delineated its rapid variation with latitude in a narrow zone of occurrence. In this short note, the relationship between vertical and oblique ionosonde observations of the phenomena is investigated and comments made on nomenclature.

Iongram range conversion applied to F2 stratification

The paper by Lynn et al (2000) used a mix of oblique ionograms over paths of varying length as well as vertical ionograms to investigate the stratification of the equatorial F2 region. The inter-relationship here may not be immediately obvious to all since the analysis of oblique ionograms appears to be something of a dying art. An author of this report has long been involved in the conversion of oblique and vertical ionograms to a common path length for a number of practical applications (see Lynn, 1998). This technique allows a simple verification that the vertical and oblique ionograms shown in the paper of Lynn et al. (2000) do indeed represent the same phenomena. Figure 1 shows the conversion of a vertical ionogram , as observed at Vanimo, Papua New Guinea to an oblique ionogram as would be expected for a path of length 1761 km with a reflection point at the same location.

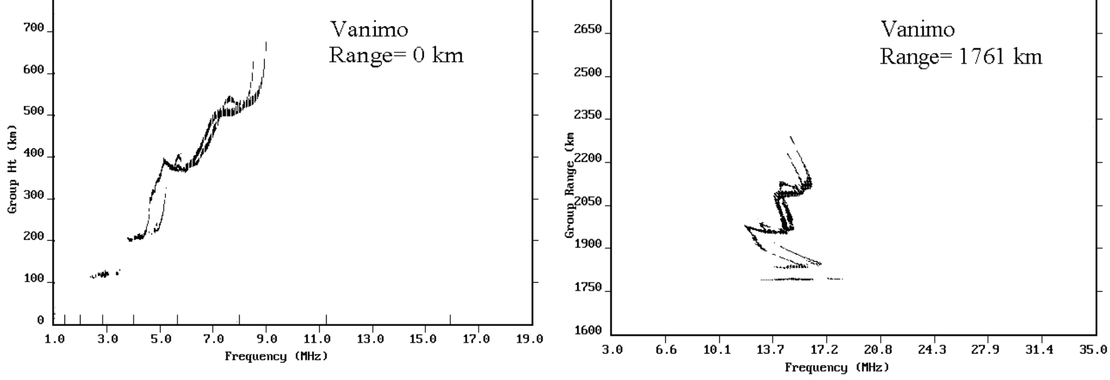

Fig.1 Vanimo vertical ionogram converted to 1761 km (10:31 LT, 2 Nov.1997).

This distance corresponds in length to a South East Asian path from Songkhla to Sumedang with a reflection point at a similar magnetic latitude to Vanimo.

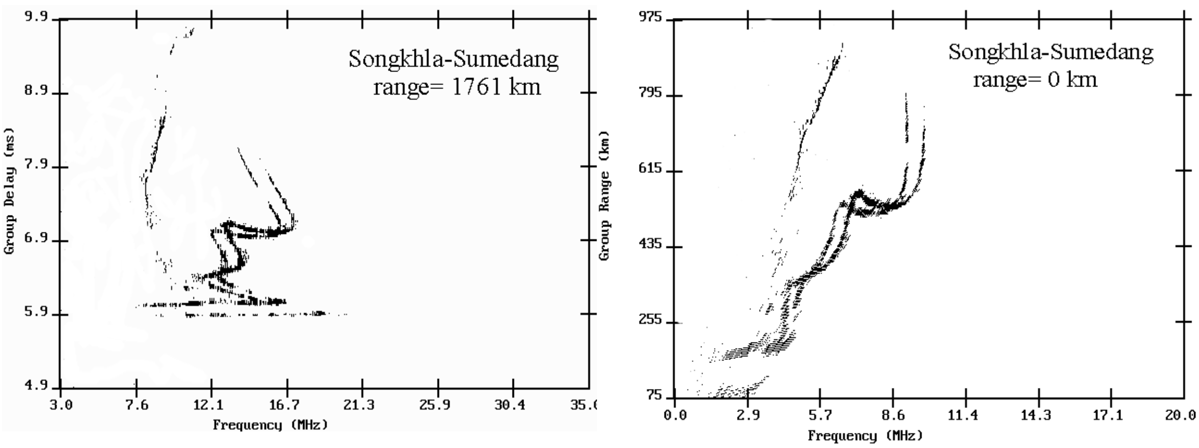

Fig.2 Songkhla-Sumedang oblique ionogram converted to 0 km (10:27 LT, 2 Nov.1997).

Figure 2 shows an observed oblique ionogram for the path Songkhla to Sumedang and the same ionogram converted to zero range. The conversion from oblique to vertical requires absolute timing for both transmitter and receiver, here provided by GPS receivers. The limited time-delay resolution of an oblique ionogram results in some error in the conversion to zero range at the lowest heights where the time delay expansion is greatest. A map showing the location of the sites discussed here is given in Lynn et al. (2000).

Together the ionograms in figures 1 and 2 demonstrate the interchangeability of vertical and oblique ionograms and their agreement in depicting the same form of F2 stratification at sites greatly separated in longitude. The vertical ionogram taken at Vanimo corresponds closely in form to that given by Balan et al. (1997) and Jenkins et al. (1997) as observed at Fortaleza, Brazil, indicating the universal nature of the phenomenon (although the individual variation from day-to-day and hour-to-hour is greater than is shown here –see Lynn et al. , 2000).

F1.5/F2/F3 What's in a name?

The nomenclature to describe F2 stratification has proved a problem. The stratification results from the distortion of the equatorial fountain effect produced by a meridional wind (Balan and Bayley, 1995, Balan et al., 1997, 1998). The early paper of Balan and Bailey (1995) described the stratification as consisting of an additional layer, the G layer, added to the existing F2 layer. In subsequent papers (e.g. Balan et al., 1997, 1998 and Jenkins etal., 1997) the G layer was renamed an F3 layer. In the paper of Lynn et al. (2000), the stratification was described in terms of a kink in the F2 profile, which could rise above the peak of the background F2 layer or remain below the peak depending on the latitude of observation. The additional layer was referred to as an F3 (in agreement with Balan etc) or an F1.5 (not recognised by Balan etc) depending on whether the transitory layer moved above or stayed below the layer which maintained continuity with the pre- and post-stratification F2 layer. This latitudinal effect was suggested as arising from the kink in the profile mapping down the field lines with increasing distance from the magnetic equator.

The name F1.5 has an ancient history and a somewhat doubtful provenance. In the present context, the name F1.5 was given to the lower layer of the stratification when this layer developed and died below the F2 peak. The F1.5 is a pre-existing nomenclature and was thus used. However it suffers from the disadvantage of suggesting that this layer is below the F2 and possibly associated with the F1. However the observations of Lynn et al. (2000) clearly showed that the base of the F2 layer maintained continuity throughout the period of stratification, as observed over the path Songkhlar-Sumedang. All layers produced by the stratification appear to exist as a distortion of a normal F2 layer and a preferable nomenclature would associate them with the F2 layer in some way. Some possibilities include F2-, F2, F3 or F2-, F2 , F2+ or F21, F22, F23 etc. Occasionally even these descriptions will require modification at times (usually brief) when the F2 has two kinks in the profile giving rise to 3-4 apparent layers in the F2. If a straight forward counting nomenclature is used, then it may also be helpful to try and identify the layer peak, which reverts to the F2 peak post-stratification. In any case, some consistent means of identification would be helpful in attempting to scale stratified ionograms. Perhaps some readers of this bulletin could make suggestions.

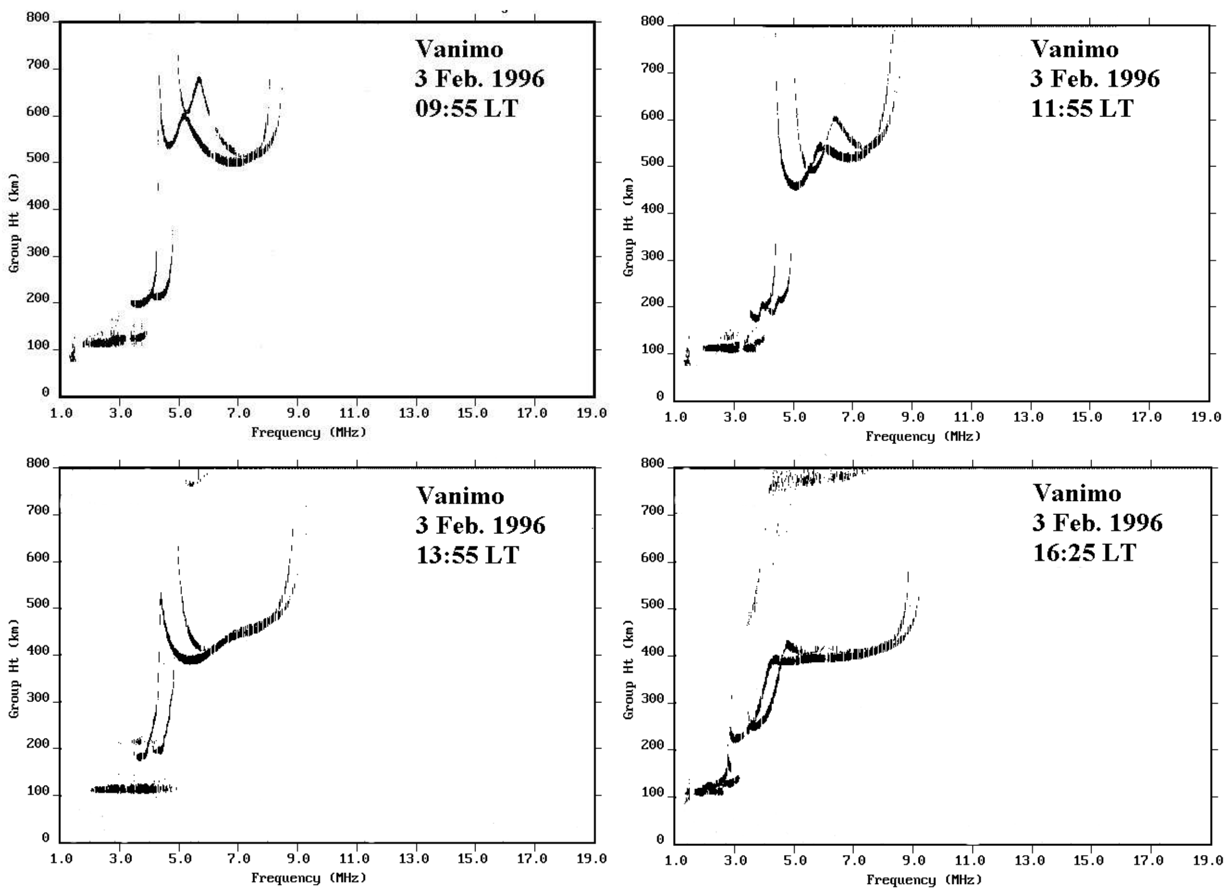

Fig.3 A sequence of ionograms showing the evolution and decay of the F2 stratification at Vanimo in February 1996.

Figure 3 shows a sequence of ionograms taken at Vanimo at sunspot minimum in which the stratification is represented by a kink towards the base of the F2 layer profile which produces an additional cusp in the F2 ionogram trace. The kink shows little movement during the day and slowly fills in, leaving an undistorted F2 profile as sunset approaches. In the nomenclature of Lynn et al. (2000), the stratification would be described as consisting of F1.5 and F2 layers while perhaps a better description would be F21 and F2. In this case, which was typical for this location at this time and year, there is nothing which could be described as an F3 layer since the peak of the F2 was never altered.

Finally there is the question of why the existence of F2 stratification has taken so long to be recognised as a standard feature of the equatorial ionosphere. History here would suggest that only a theoretical explanation can turn an apparent experimental anomaly into a recognised event. One wonders if there any more of such overlooked phenomena.

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