ROCKET AND IONOSONDE STUDIES OF MIDLATITUDE SPREAD F

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ABSTRACT

A statistical study of Midlatitude Spread F (MSF) at Wallops Island (37.8°N, 284.53°E) has been conducted using both ground-based and in-situ data. Ionosonde data have been processed and the results show that MSF has strong seasonal and a solar cycle variations. A rocket was launched into MSF from Wallops Island on October 30, 2007 at 12:12 AM. The rocket data are currently being analyzed and will be used to determine electric fields and winds associated with active MSF. Density data from the rocket will give additional insight into the small scale structure of MSF.

INTRODUCTION

Ionospheric irregularities are temporal and spatial variations of the electron density lasting from a few minutes up to several hours. In the lower latitude regions such irregularities exhibit structure over a large range of scale sizes; the phenomenon is called Equatorial Spread F. Occurrence of similar irregularities in the midlatitude F region is called Midlatitude Spread F (MSF), but at midlatitudes the mechanism of formation of spread F is not well understood. Gravity waves are widely recognized as a necessary precondition which potentially cause these density perturbations in the F region [*Kelley & Fukao, 1991; Oliver et al., 1994*].

The O-Mode ionogram trace is used to identify MSF occurrence. Ionograms obtained during MSF events show thickness or spread in the F region trace that is significantly greater than that obtained for a normal ionosphere. Panel 1 in ***Figure 1*** shows a normal ionogram on 20 November 2004 at 6 UT, and panel 2 shows a spread event on 1 November 2003 at the same local time. The latter ionogram shows a thick trace which implies strong MSF.

The spread observed on the ionograms can be classified as range or frequency spread. **Range spread** refers to a condition in which there are multiple range echoes at a particular frequency. **Frequency spread** refers to the case in which multiple critical frequencies appear at fixed altitudes. The boxes shown in ***Figure 2*** are positioned by our autonomous edge detection software. Large pixel counts in box 1 correspond to range spreading, and large pixel counts in box 2 correspond to frequency spreading.

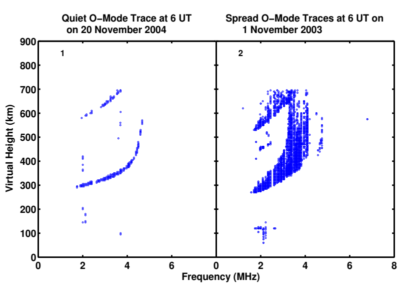

FIGURE 1 – Left panel shows a midlatitude non-spread F event at Wallops Island on 20 November 2004 at 6 UT. The right panel shows a midlatitude spread F event at Wallops Island on 1 November 2003 at 6 UT.

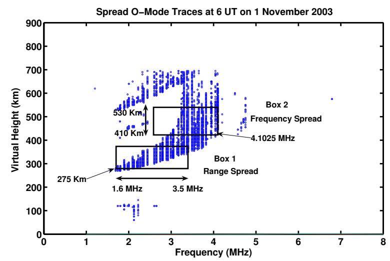

FIGURE 2 - Boxes drawn representing the pattern recognition algorithm for identifying frequency and range spread F.

DATA PRESENTATION- IONOSONDE

Our dataset is comprised of nighttime ionograms at 15 minute intervals. The database enables determination of both the seasonal and solar-cycle variations of midlatitude spread F at Wallops Island. ***Figures 3-4*** illustrate these findings.

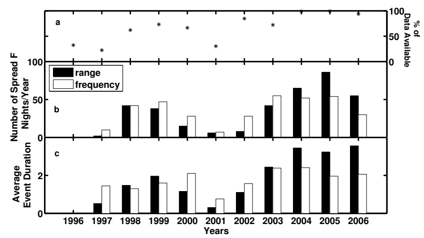

FIGURE 3 – Panel a displays the percentage of data available in each year for the entire solar cycle. Panel b shows the number of spread F nights/year for an entire solar cycle from 1996-2006. Panel c shows the average number of spread hours/night.

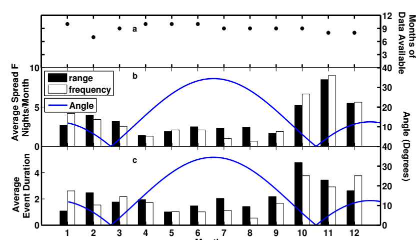

FIGURE 4 – Panel a shows months of data available over the solar cycle. Panel b shows the number of spread F nights/month averaged over an entire solar cycle from 1996-2006. Panel c shows the average hours of spread F/night for each month. The line represents the angle between the dusk terminator and the local magnetic field.

Figure 5 highlights the relationship between F10.7 solar flux and range spread F duration during solar maximum (2000) and solar minimum (2005).

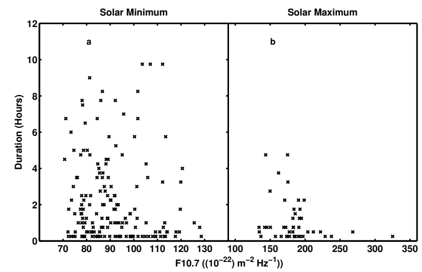

FIGURE 5 – Hours of range spread F vs. F10.7 for solar maximum (right panel) and solar minimum (left panel). The horizontal axes are different for the two panels.

DATA PRESENTATION - ROCKET

The raw telemetry data for the electric field and two pressure ratio channels used for measuring wind direction and amplitude are displayed in ***Figure 5.*** ***Figure 6*** displays the wind amplitude and direction obtained from the phases of the pressure ratio channels combined with knowledge of the rocket's attitude.

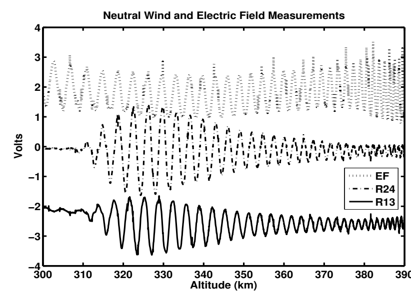

FIGURE 6 – Raw rocket data showing electric field and neutral pressure ratios for wind direction and amplitude measurements during active MSF at Wallops Island.

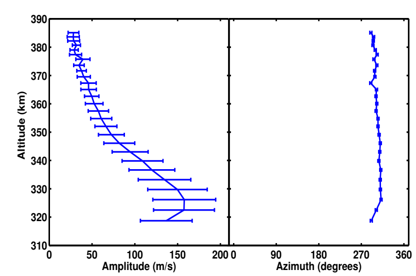

FIGURE 7 – Wind vector versus altitude in active MSF.

DISCUSSION

It is evident from ***Figure 3*** that MSF occurs more frequently during solar minimum (2005) than during solar maximum (2000). This is true for both the number of spread F occurrences and the average spread F duration. Since gravity waves are considered the precursor for MSF, the propagation conditions for these waves are expected to be important determining factors in such statistics. During solar minimum, gravity waves have larger amplitudes at F-region heights, while at solar maximum they propagate to higher altitudes [*Vadas, 2007*]. Our statistics suggest that the amplitude of the gravity waves is the more important factor in generating MSF. ***Figure 3*** also shows that range spread F is more prevalent at solar minimum and frequency spread F is more prevalent at solar maximum. Numerical modeling may help to understand this relationship.

Figure 4 shows the seasonal variation of MSF over Wallops Island. Both range and frequency spread F occur more often and for longer duration during the fall and winter seasons. Another observation which can be made from this figure is that the angle of the evening terminator with respect to the magnetic declination at Wallops is near zero during the months of February and October, coincident with the longest duration range spreading events. This suggests that electric field mapping between conjugate hemispheres may be important to the generation and/or duration of MSF.

Figure 5 shows the comparison between solar minimum and solar maximum for range MSF duration vs. F10.7. There are many more events of longer duration during solar minimum (2005). The solar maximum year (2000) shows that for F10.7 greater than 200 there are very few MSF events, and no long lived events. For F10.7 below 200 there are a few more long duration events, but still relatively few compared to solar minimum. No explicit correlation exists between F10.7 and MSF duration for either year, in contrast to an earlier study performed in Australia [*Bowman, 1994*] using only 3 months of data.

The raw rocket data have been plotted in ***Figure 6.*** The electric field measurement and the two pressure ratio channels used for measurement of wind direction and amplitude have been plotted vs. altitude for the upleg portion of the flight.

Figure 7 shows that the wind during this spread F event was in the north-west direction, which is consistent with conditions required for the Perkins instability *[Perkins, 1973]*.

FUTURE WORK

- Determine the electric field vector from the rocket data.
- Use wind, electric field and plasma density results to get a complete small-scale picture of MSF.
- Building a 2-d numerical model to study the interactions between RF sounder signals and the structured bottom-side of the F region.

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FOR FURTHER INFORMATION

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