On the observations and spectral features of atypical F-region echoes

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1. INTRODUCTION

- Recent radar observations (Patra et al., 2009; Yokoyama et al. 2011; Nishioka et al. 2012) showed that equatorial spread F events (ESF) can occur, more often than expected, during June solstice and after midnight (atypical ESF).
- In Brazil, most observations were made in the pre-midnight and regular ESF season (August- April). During June and July in 2011 (~95 SFU), the FCI radar was first operated to make full night (18:00 - 08:00 LT) observations of the F-region and it was found that pre/post-midnight echoes appeared nearly every night.
- The objectives of this study are: (a) to better understand the occurrence of atypical (post-midnight in particular) F-region echoes in the Brazilian sector and (b) to determine, for the first time, the spectral features of these echoes.

2. APPROACH

- The lack of adequate post-midnight ESF measurements led us to deploy the Measurements of Low-latitude and Equatorial Ionosphere irregularities over Sao Luis in South America (MELISSA) radar in Brazil 2014, which is an upgrade of the FCI radar and is operated during whole night (18:00-8:00 LT).
- Table 1 summarizes the MELISSA radar parameters used for F-region measurements and analysis parameters used for spectra estimation.
- The observations used in this study were made between March, 2014 and May, 2016, during which time the solar flux is descending from high (~ 130 SFU) to moderate (~120 SFU). For this analysis, only observations that last from 18:00 LT to at least 4:00 LT of the next day are counted, which add up to 146 full night measurements finally.

Table 1. Summary of radar parameters used in the F-region measurements

Parameter	Value
Peak TX Power	16 kW
Code	28 bit
Baud length	2.4 km
IPP	1401.6 km
Number of samples	500
Lowest height sampled	90 km
Coherent integration	None
Number of FFT points	64
Number of FFT spectra averaged	25

3. ANALYSES AND RESULTS

- In order to study atypical echoes, we computed Range-Time-Intensity (RTI) maps of observations made in each night. From these RTI maps, we identified typical and atypical (post-midnight) ESF events. The result is shown in Figure 1.

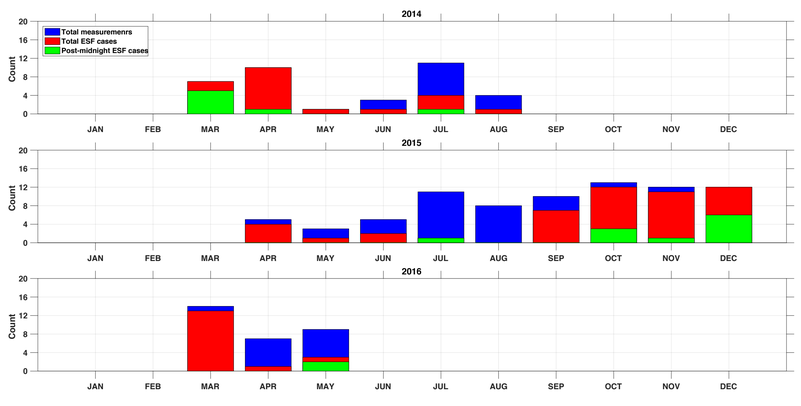

Figure 1. Histogram of measurements and ESF events identified in 2014-2016. Count refers to number of full night measurements.

- To study the spectral features of the observed echoes, we computed the Doppler spectra and fit a Gaussian model to it to estimate mean Doppler velocities and spectral widths. Examples are shown in Fig. 2.

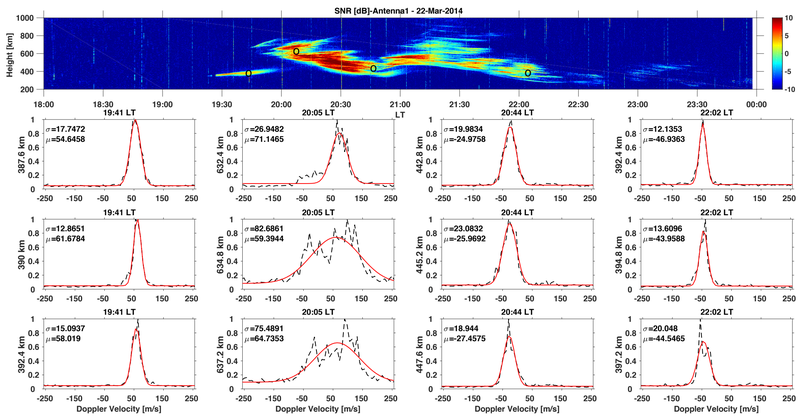

Figure 2. The top panel shows the RTI map of a typical ESF event. The bottom panels show examples of spectra estimated from observations made at different heights and times. σ and μ in each panel represent the estimated spectrum width and mean Doppler velocity, respectively.

Spectral analyses such as those shown in Fig. 2 indicate that topside spectra are, typically wide and vary with height (2nd column). The bottom-type echoes (1st column), on the other hand, are narrow and do not seem to change much with height. Finally, bottomside echoes (3rd and 4th columns) are not as wide (narrow) as topside (bottom-type) echoes, and the mean Doppler velocity can change noticeably with height.

- Our analyses of the measurements led us to suggest three types of post-midnight events. Examples are shown in Figure 3-5.

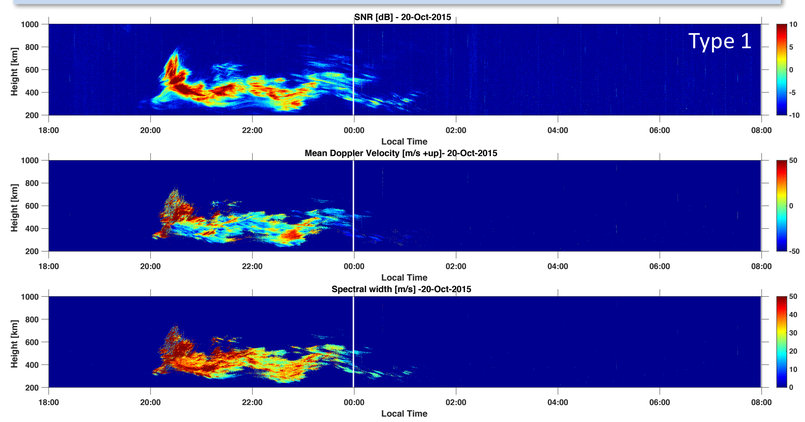

Figure 3: Type 1 post-midnight echoes: An ESF event appears after sunset and continues to post-midnight hours. The top, middle and bottom panels show the RTI map, mean Doppler velocities and spectral widths, respectively.

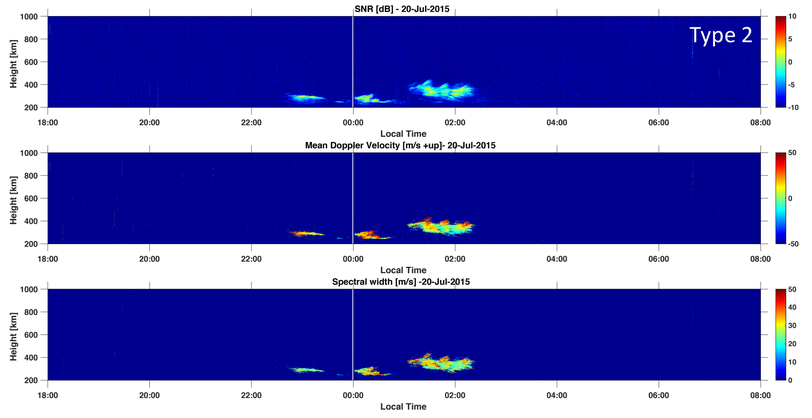

Figure 4. Type 2 post-midnight echoes: The same as figure 3 but for an ESF event that starts late in the pre-midnight sector and continues to post-midnight hours.

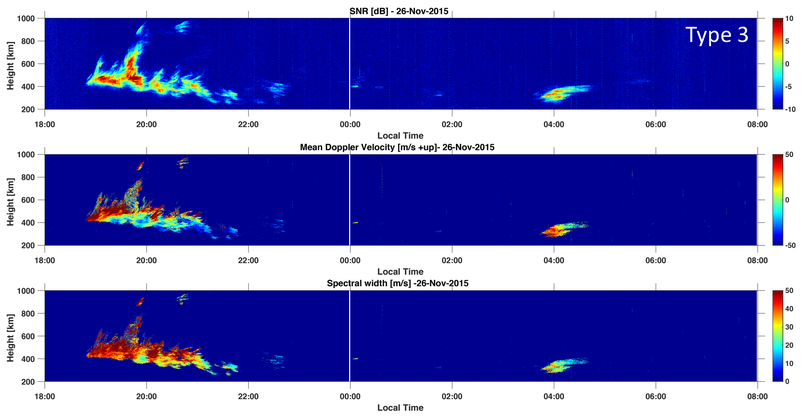

Figure 5. Type 3 post-midnight echoes: The same as in figure 3 but for a post-midnight ESF event that appears to be unrelated to the pre-midnight case.

- In our set of 146 nights we observed a total of 19 cases (13%) with post-midnight echoes.
- Of the 19 cases, only 2 cases were found around June solstice (June/July).
- Interestingly, we found that both cases were of type 2, that is, they started late in pre-midnight sector and continued to post-midnight hours. The other two type-2 cases occurred in May.

While post-midnight June solstice echoes were observed in the past (2011), the collection of data during that time did not allow us to determine their spectral features.

To learn more about the atypical June solstice ESF cases, we analyzed the distribution of spectral widths and mean Doppler velocities made by MELISSA during the observed events. Figure 6 shows our results.

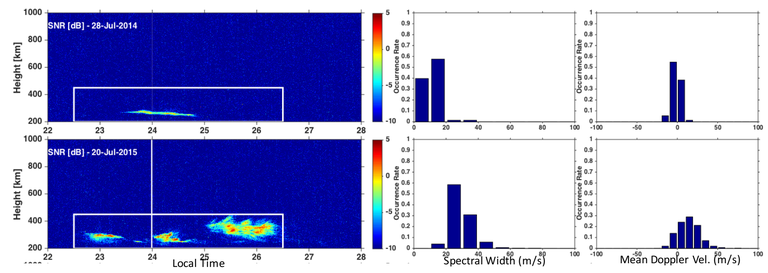

Figure 6. Cases of atypical June solstice ESF events observed by MELISSA. The left columns show the RTI maps, while the other columns show histograms of spectral widths and mean Doppler velocities. The histograms are shown only for echoes with SNR > 0 dB.

- The measurements in Figure 6 show that June solstice events do not reach altitudes greater than ~ 400 km.
- The Jul-2014 resembles a bottomtype layer, and the Jul-2015 event resembles an underdeveloped plume (bottomside) layer.
- The events are characterized by, mostly, small or positive mean Doppler velocities spectral widths less than ~60 m/s.

4. SUMMARY

- Typical ESF observations have been made extensively in the Brazilian sector during pre-midnight hours of the season ESF season (August-April).
- Only with the installation of MELISSA we have been able to adequately investigate the F-region irregularity conditions outside ESF season and during post-midnight hours.
- The observations and analyses (such as those shown here) provide new insight about the stability of the F-region in the Brazilian sector:
  - The detection of irregularities around midnight hours indicate the operation of an instability that finds favorable conditions during those particular hours.
  - The similarity to pre-midnight events (in echo distribution and spectral features) suggest the potential for instability processes similar to those observed near sunset hours during ESF season.
  - The low irregularity occurrence in 2014 (~ 130 SFU) and 2015 (~120 SFU) provides additional evidence of the hypothesis that June solstice irregularities are strongly modulated by solar flux conditions.
- We will continue our measurements during June/July 2016 when solar flux conditions are expected to be lower than those in 2014 and 2015.

REFERENCES:

1. Nishioka, M. et al., On post-midnight field-aligned irregularities observed with a 30.8-MHz radar at a low latitude: Comparison with F-layer altitude near the geomagnetic equator, J. Geophys. Res., 117, A08337, 2012.
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