



# **ROCKET OBSERVATIONS OF ANOMALOUS ELECTRON TEMPERATURES BELOW THE F- LAYER**

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UFRN/CLBI, Natal-RN



# INTRODUCTION

In-situ measurements made from Brazil using rocket-borne swept-bias Langmuir Probes on 3 occasions are presented here.

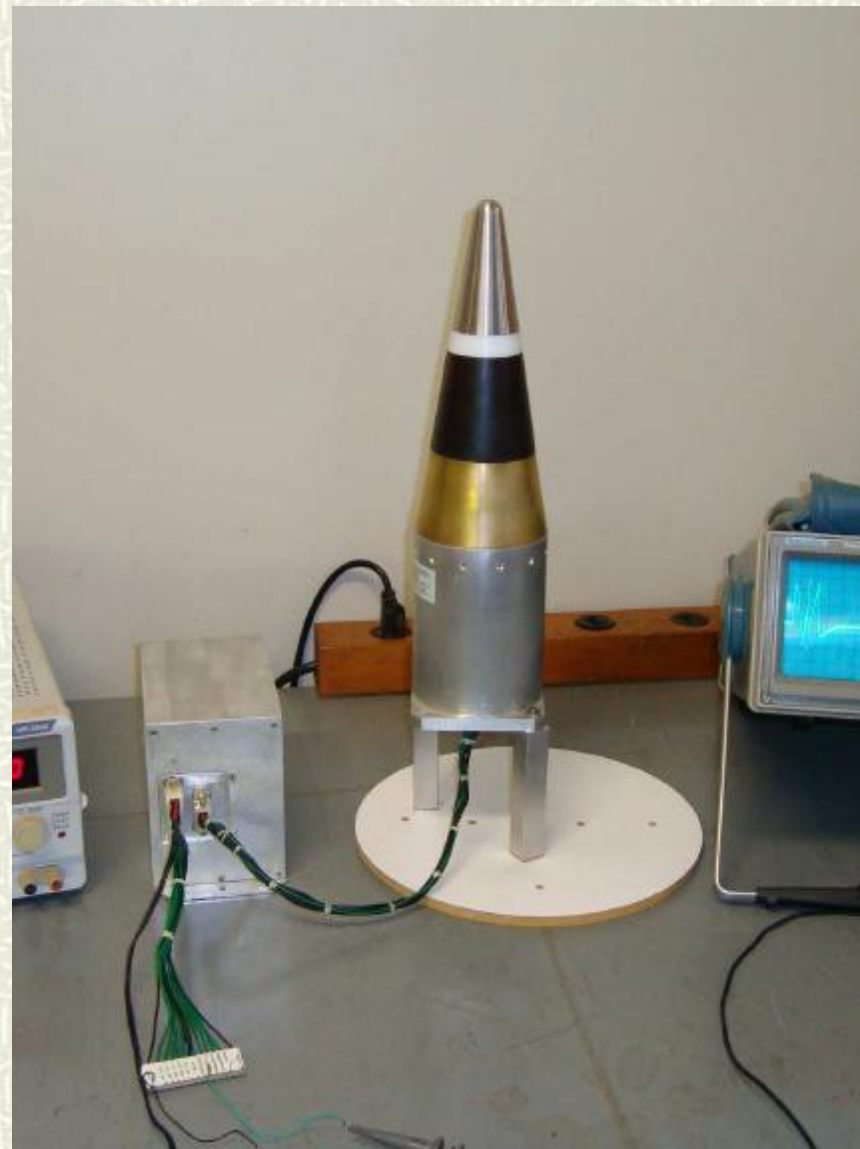
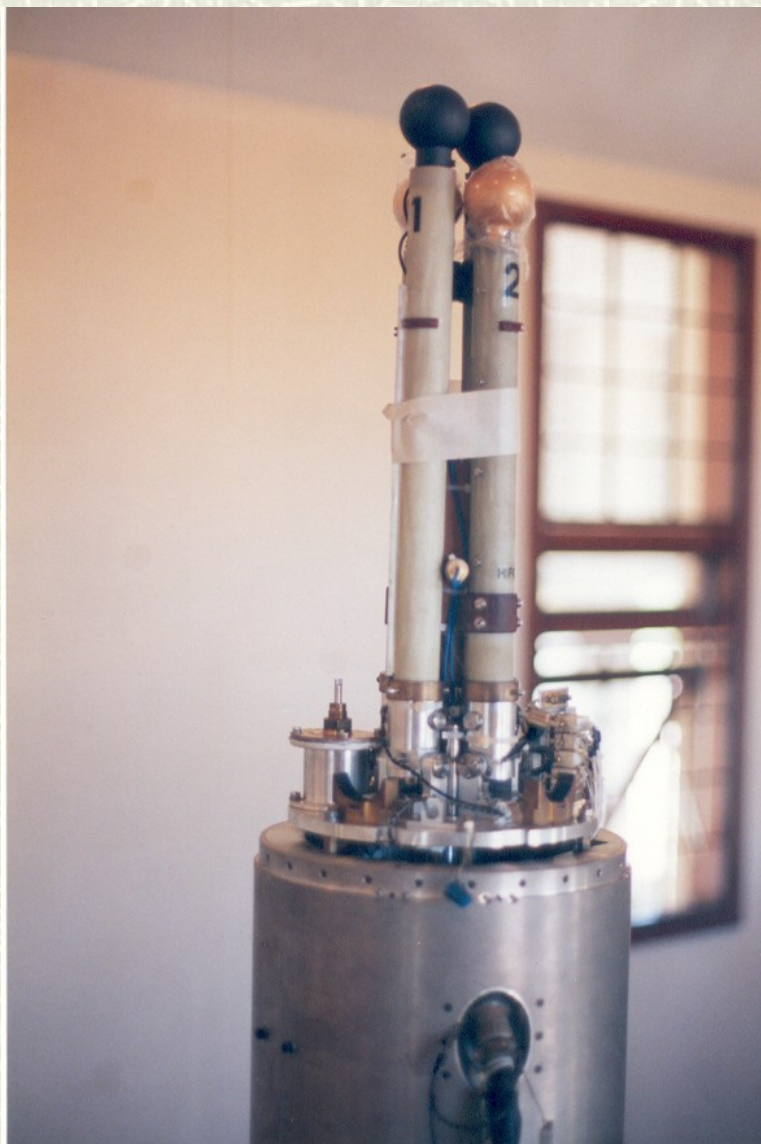
- ❖ SONDA III launched at 21:17Hrs (LT) on 18-th December 1995 from Alcântara, Brazil (Geog.  $2^{\circ} 24'S$ ,  $44^{\circ} 25'W$ ).
- ❖ VS-30 launched at 19:00Hrs on 2-nd December 2011 from Natal, Brazil (Geog.  $5^{\circ} 48'S$ ,  $35^{\circ} 13'W$ ) using a VS-30 Brazilian rocket.
- ❖ VS-30/Orion V10 2 stage rocket launched at 19:00 Hrs on 8-th December 2012 from Alcântara, Brazil.

# Langmuir Probe



SONDA III – IONEX, 1995

VS-30, 2011  
VS-30/ORION, 2012





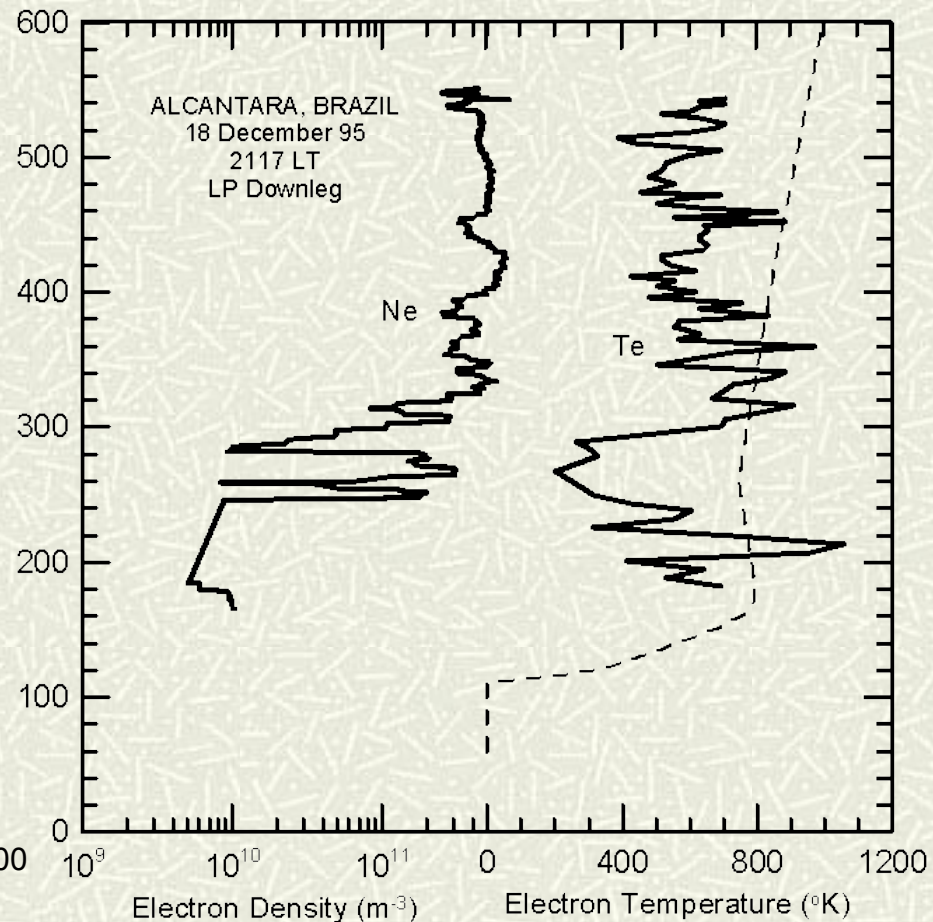
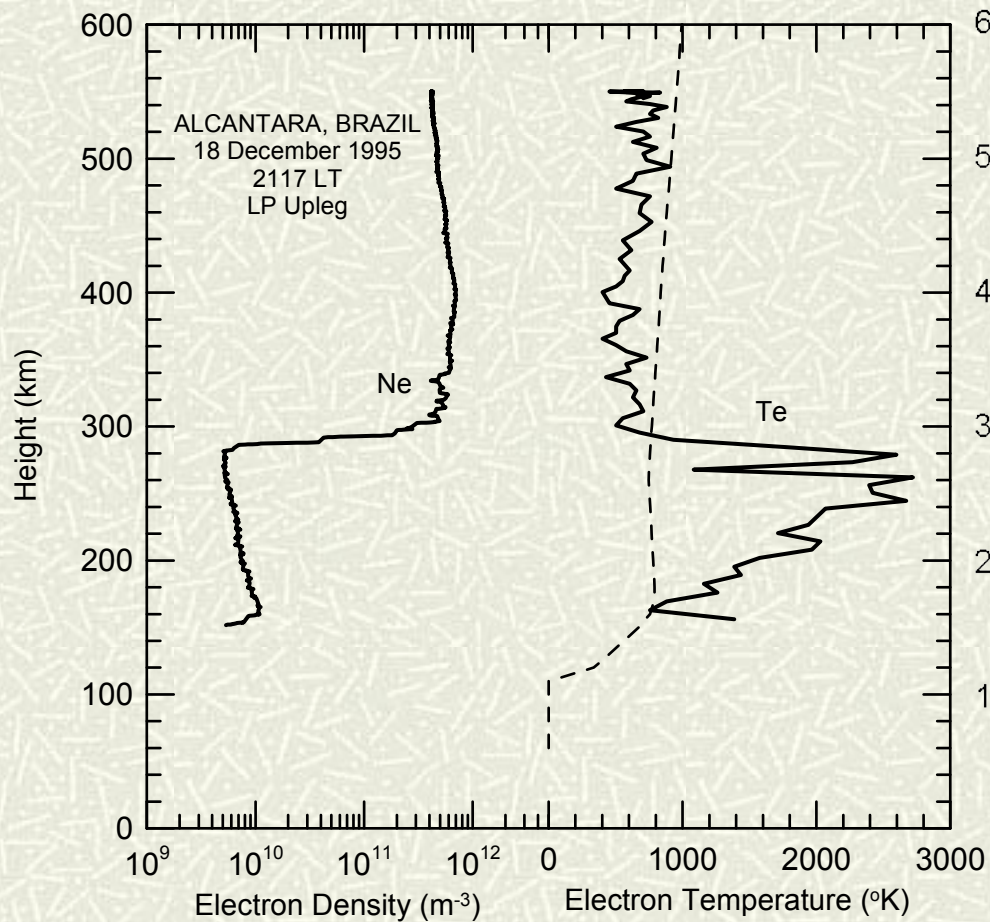


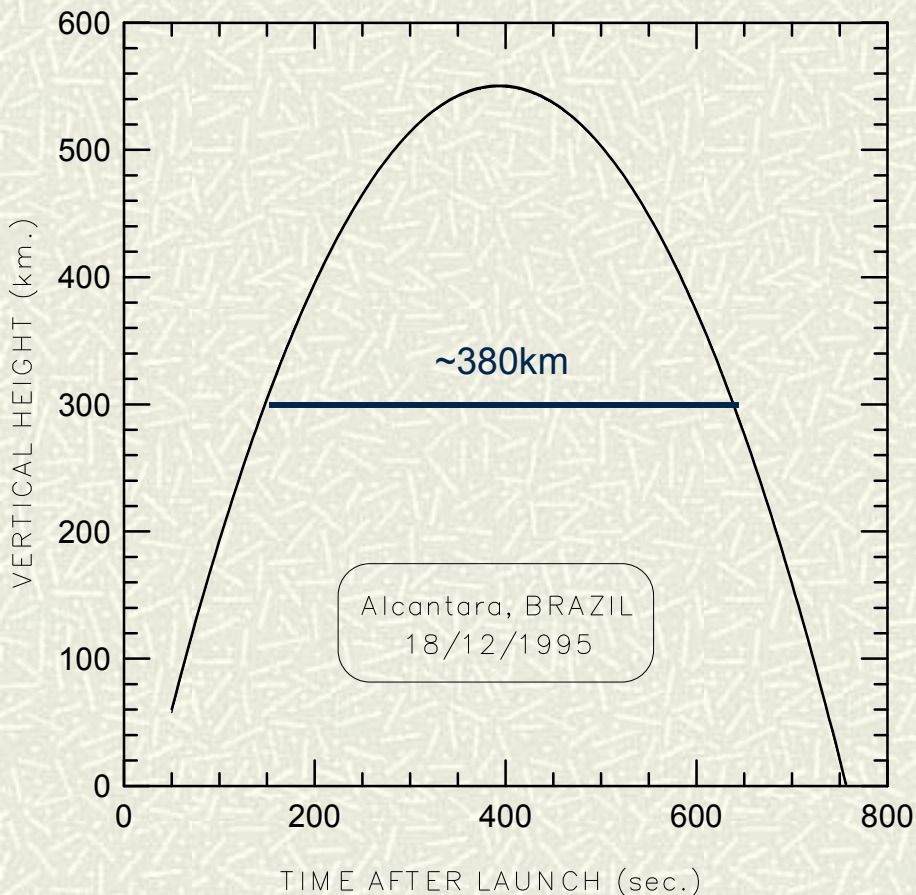
# OBSERVATIONS

- ❖ On all the occasions the electron temperature in the valley region between the equatorial E and F regions showed abnormal values soon after sunset hours.
- ❖ The ground equipments operated before and during the rocket launch clearly showed the presence of Spread-F irregularities in the F-region. At the time of launch the spread-F activity was at its peak.
- ❖ The relationship between the abnormal temperatures observed below the F-layer, the vertical drift of the F-layer and the formation of plasma bubbles is investigated here.



# Launch at 21:17Hrs on 18/12/1995





❖ This multiple experiment launch, designated IONEX was made under spread-F conditions and the rocket reached an apogee altitude of 550km and horizontal range of 580km.

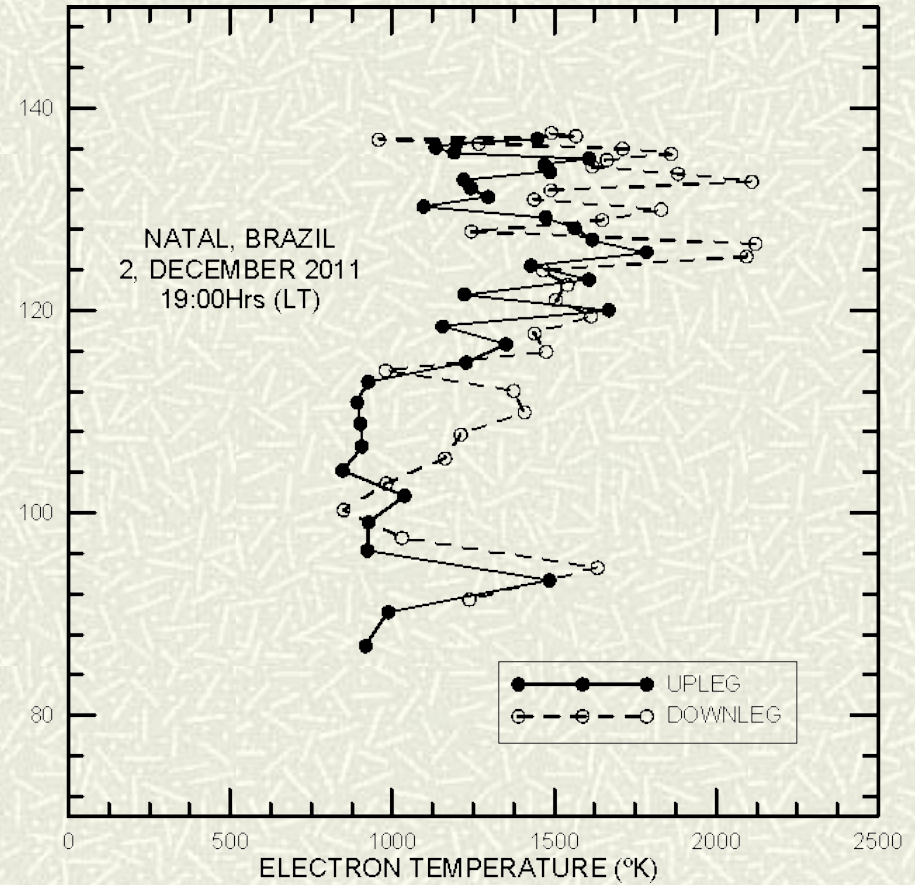
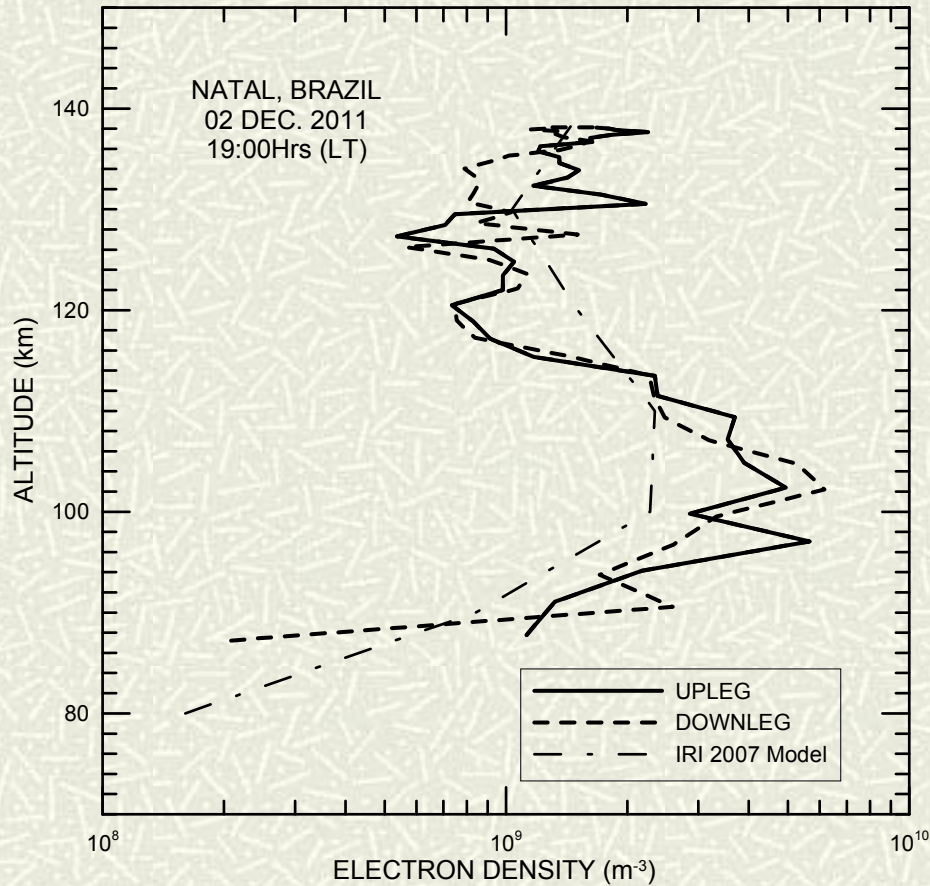
❖ During upleg the electron density profile showed an undisturbed but high F-layer while during downleg showed the presence of several plasma bubbles.

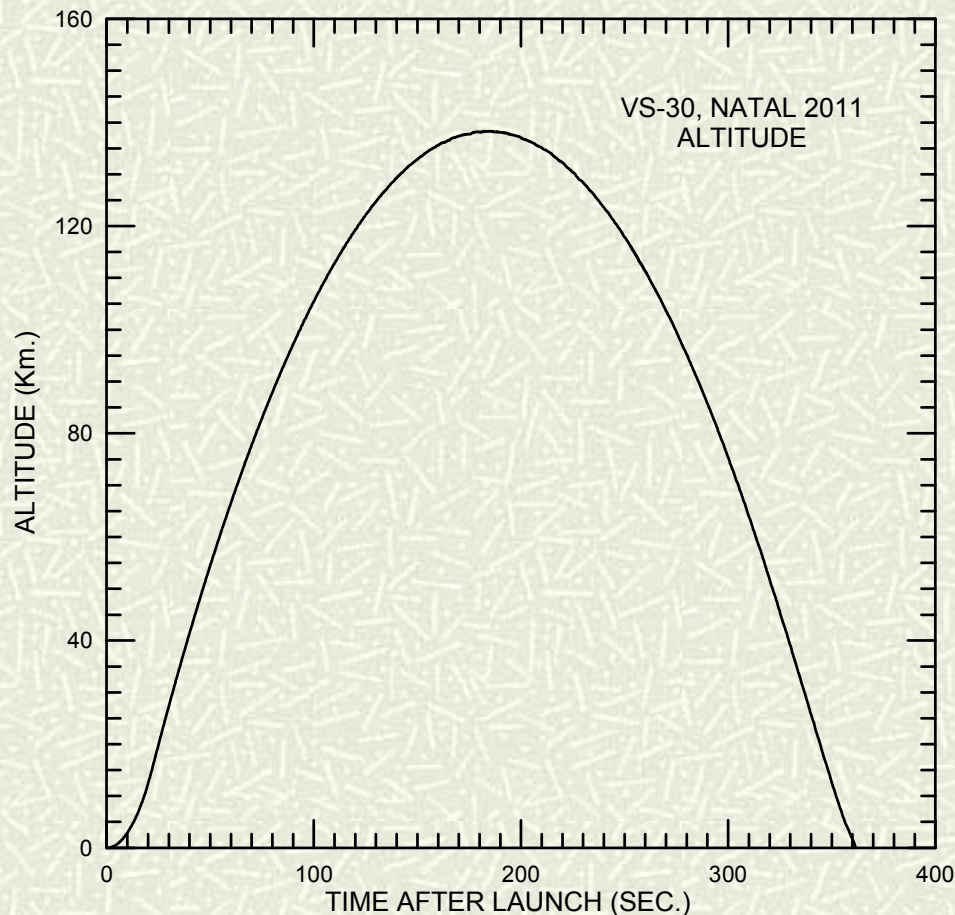
❖ During upleg the valley region below the F-layer showed the presence  $T_e$  as high as 2000°K while during downleg  $T_e$  profile showed rather normal values indicating that the abnormal  $T_e$  observed during upleg got dissipated.





# Launch at 19:00Hrs on 02/12/2011





❖ This launch was made soon after sunset under spread-F conditions and the rocket reached an apogee altitude of 140km and horizontal range of 130km.

❖ During both upleg and downleg the electron density profile showed large amplitude fluctuations in the valley region below the F-layer.

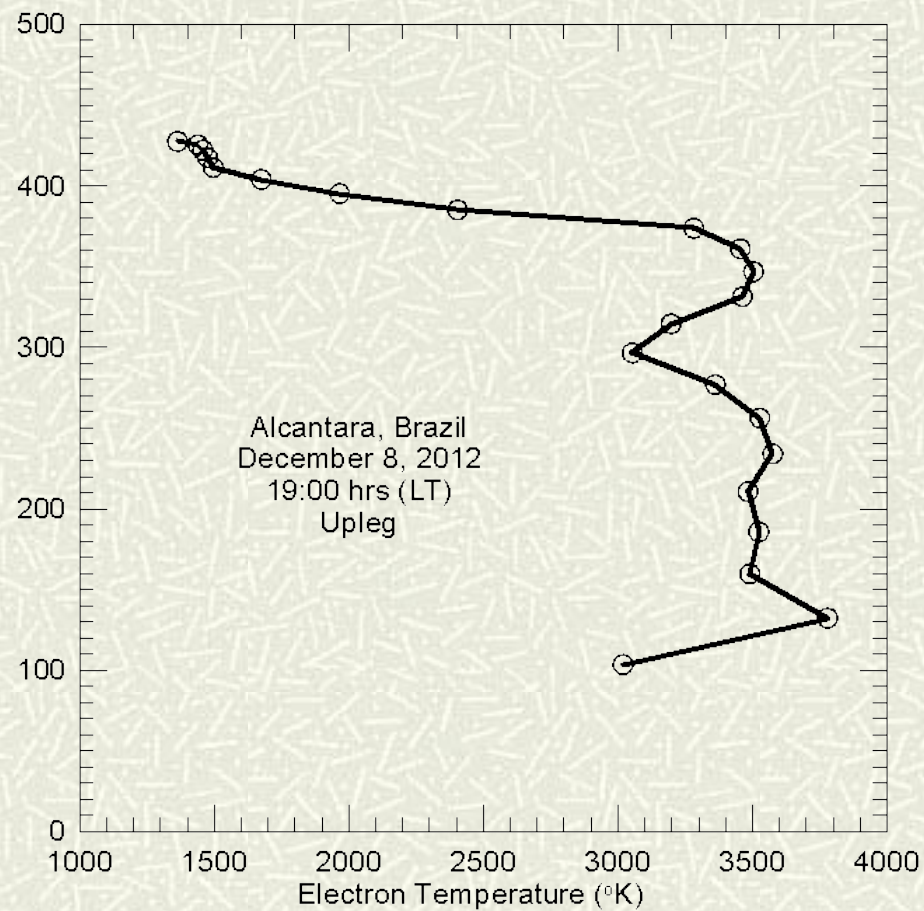
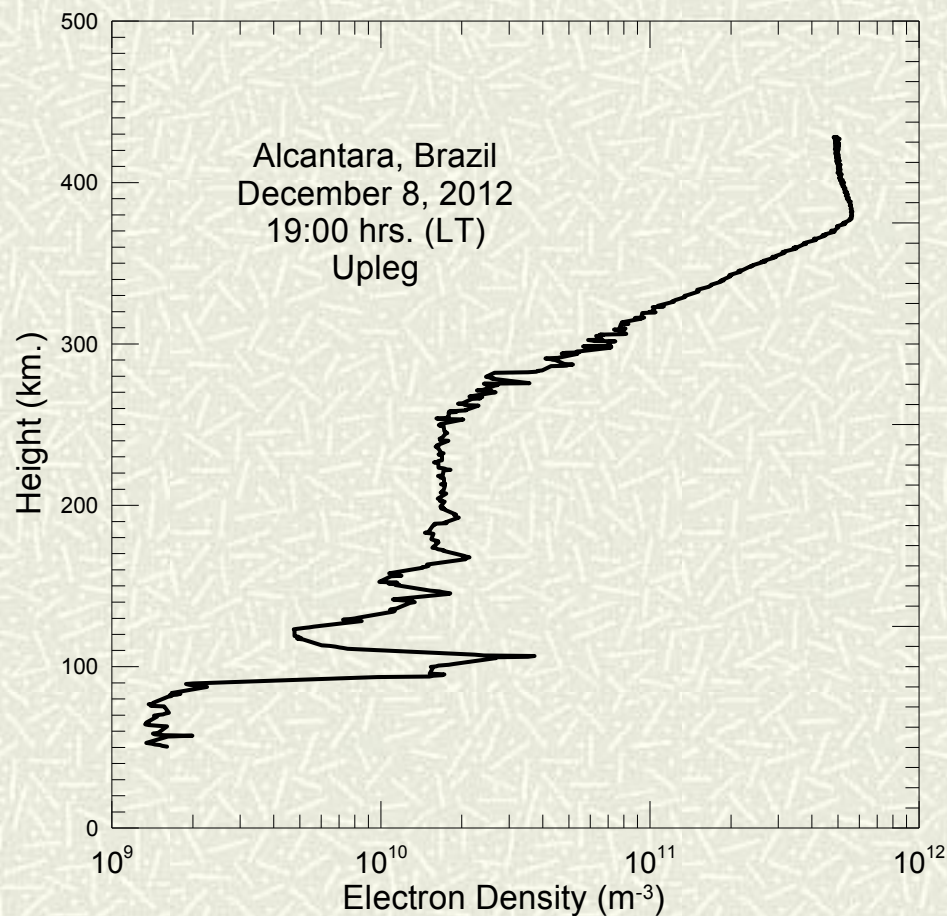
❖ Electron temperature profile estimated from the LP data also showed large amplitude fluctuations mostly anticorrelated with the electron density fluctuations





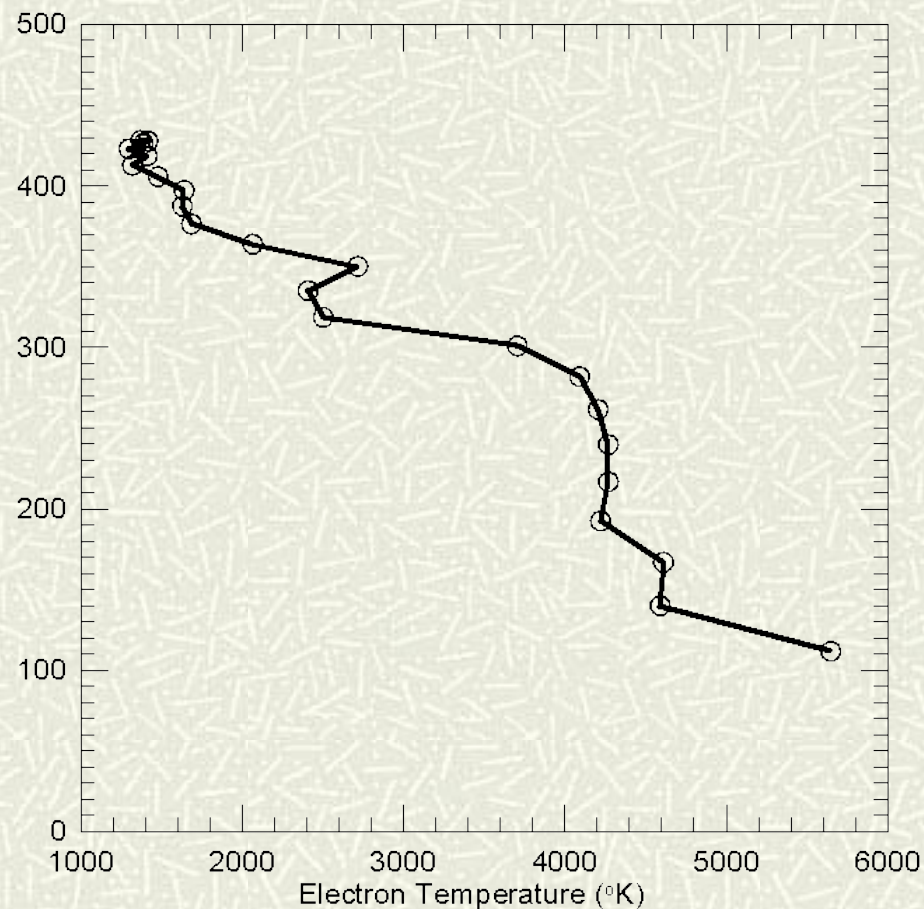
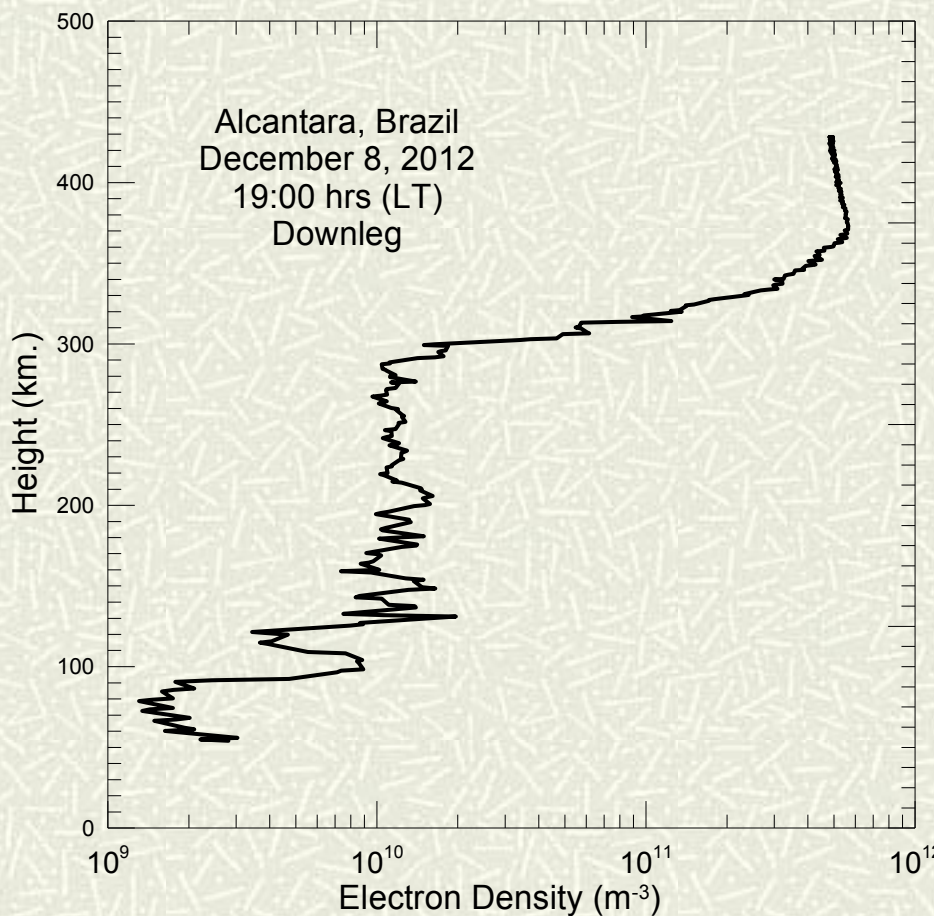
# Launch at 19:00Hrs on 8/12/2012

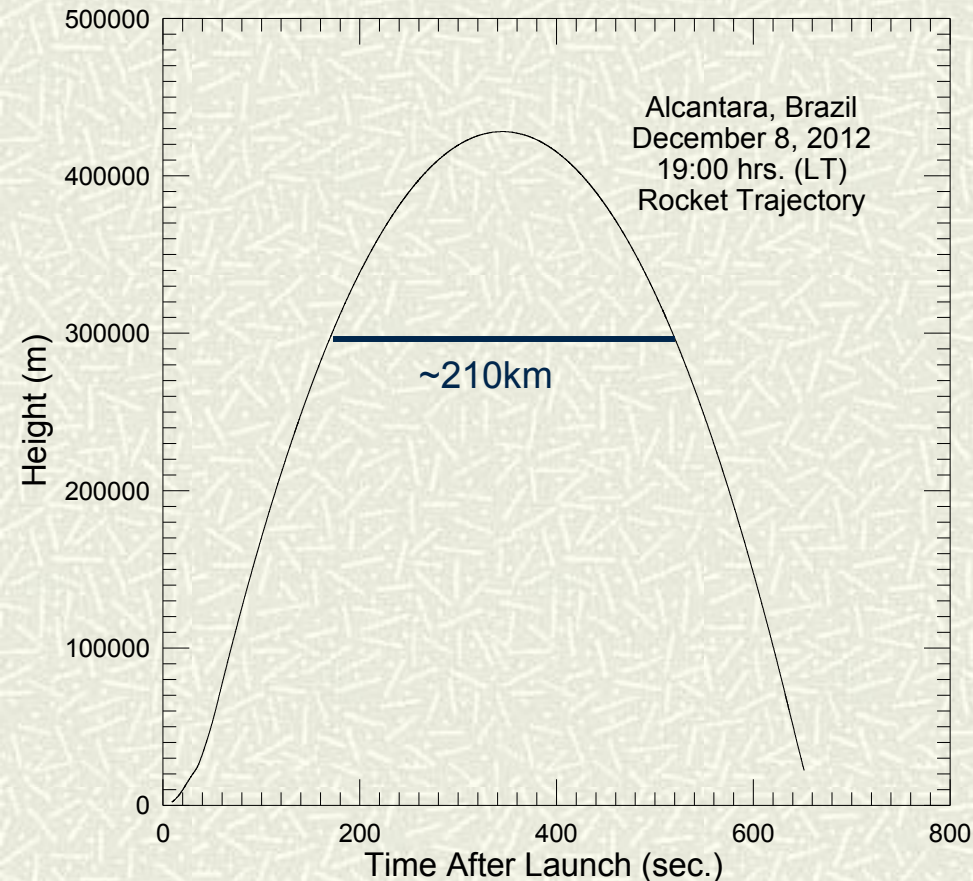
## Upleg Profiles





# Downleg Profiles



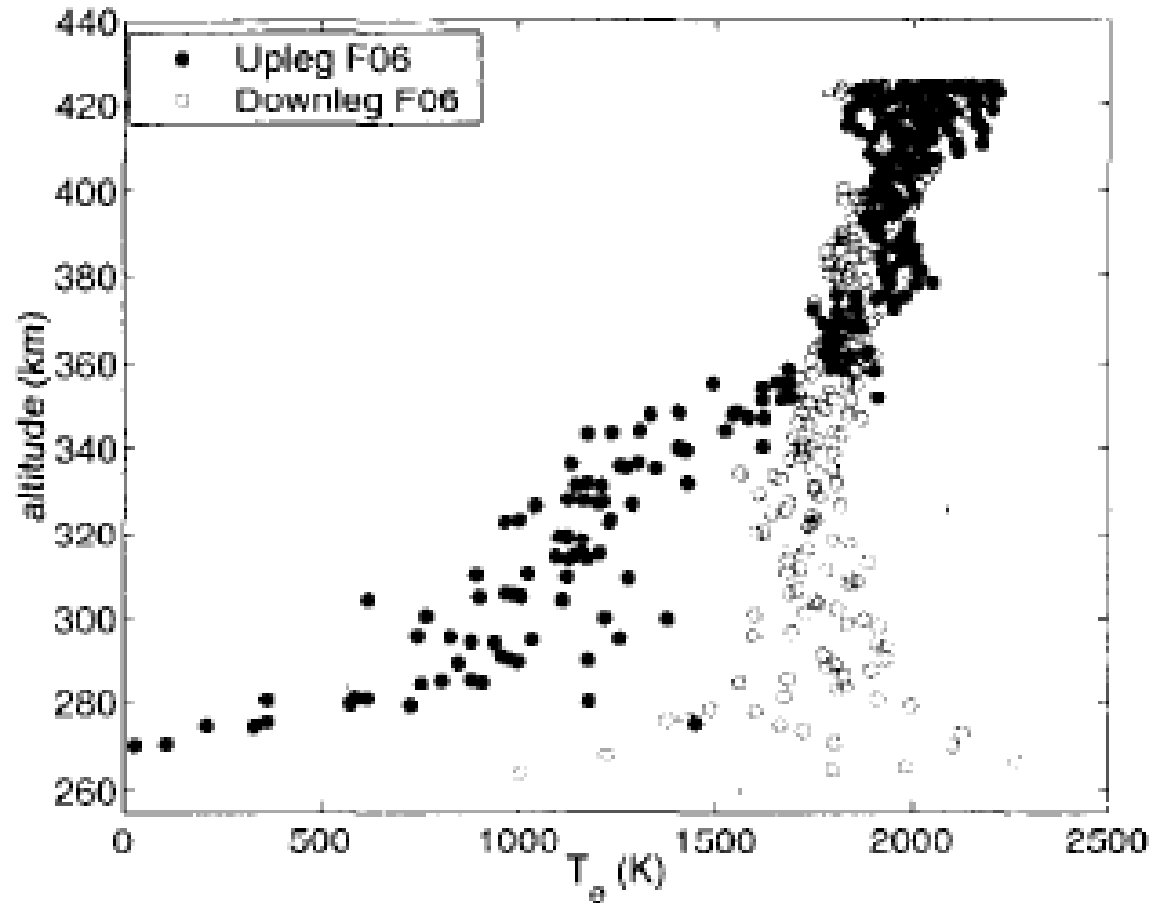


❖ This launch was also made soon after sunset under spread-F conditions and the rocket reached an apogee altitude of 428km and horizontal range of 383km.

❖ During both upleg and downleg the electron density profile showed large amplitude fluctuations in the valley region below the F-layer.

❖ Electron temperature profiles estimated from the LP data showed abnormally high  $T_e$  values ( $> 3500$  °K ) during both upleg and downleg in the valley region, with large amplitude fluctuations.





Electron Temperature profiles from LP on Deos Flight at 19:21 LT from SHAR, India by Steigies et al. (Adv. Space Res., 2002). They attributed the abnormal  $T_e$  observed during downleg to distortions in the LP characteristic curve due to surface contamination

# DISCUSSION



## Prereversal Enhancement in the Vertical Plasma Drift (PRE):

- It is now well known that in the low latitude region the vertical plasma drift exhibits a pre-reversal enhancement (PRE) in the evening hours. The PRE also exhibits a seasonal variation.
- PRE in the vertical plasma drift is mainly attributed to the increase in the driving electric fields associated with sunsets in the E-region altitudes conjugate to the F-region altitudes considered.
- Present observations indicate that the valley region is extremely active during the sunset period with the presence of large  $T_e$  values and also the presence of large amplitude waves.

## Vertical Drift of F-Layer Close to Sunset



- ❖ The PRE in the plasma drift is also normally associated with vertical drift in the F-layer base as observed by Ionosondes e Digisondes.
- ❖ One must take care not to interpret the height increase in the F-layer as PRE in the plasma drift.
- ❖ The height of the F-layer can increase due to the rapid rise of the solar terminator close to sunset hours that will almost immediately affect the electron number density in the region where the solar radiation is cut off, below the base of the F-region.





❖ For the tropical latitudes the height of solar terminator after sunset and the vertical velocity of terminator are given by:

$$h = R_0 \left[ \sec \frac{2\pi t}{T} - 1 \right]$$

$$\frac{dh}{dt} = \frac{2R_0\pi}{T} \sec \left( \frac{2\pi t}{T} \right) \cdot \tan \left( \frac{2\pi t}{T} \right)$$

t - is the time after ground sunset,  
h- is the solar terminator height,  
T- is 24x60 minutes.

t (min)	h (km)	dh/dt (m/s)
40	98.3	83
50	154.7	105
60	224.7	128
70	309.1	153
80	408.8	179

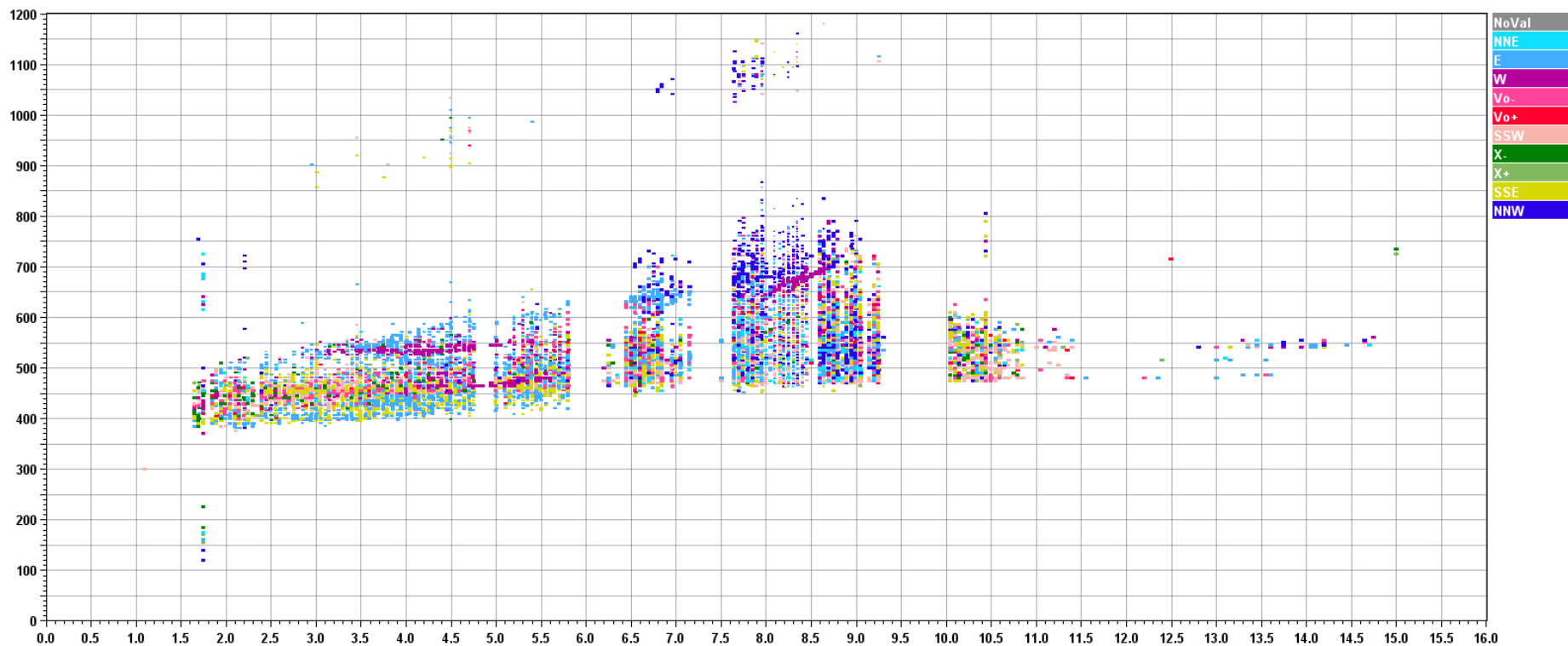
[Obs: In the month of December, sunsets at magnetically conjugate latitudes of the launch stations occur practically simultaneously]



# Fortaleza ionogram at the time of launch on Dec. 2, 2011 Showing strong Spread-F activity

Fortaleza, FZA0M

2011.12.02 (336) 22:00:00.000 \_I\_



SAOExplorer, v 3.4.3

Ground sunset time: 17:33Hrs.  
300km sunset time: ~18:43Hrs.

# São Luís Ionogram observed on Dec. 8, 2012 at the time of launch Showing Spread-F activity



Station YYYY DAY DDD HHMMSS P1 FFS S AXN PPS IGA PS  
 SaoLuis 2012 Dec08 343 220000 RSF 005 2 713 100 10+ 22

foF2 4.350  
 foF1 N/A  
 foF1p N/A  
 foE N/A  
 foEp 0.48  
 fxI 4.85  
 foEs N/A  
 fmin 1.60

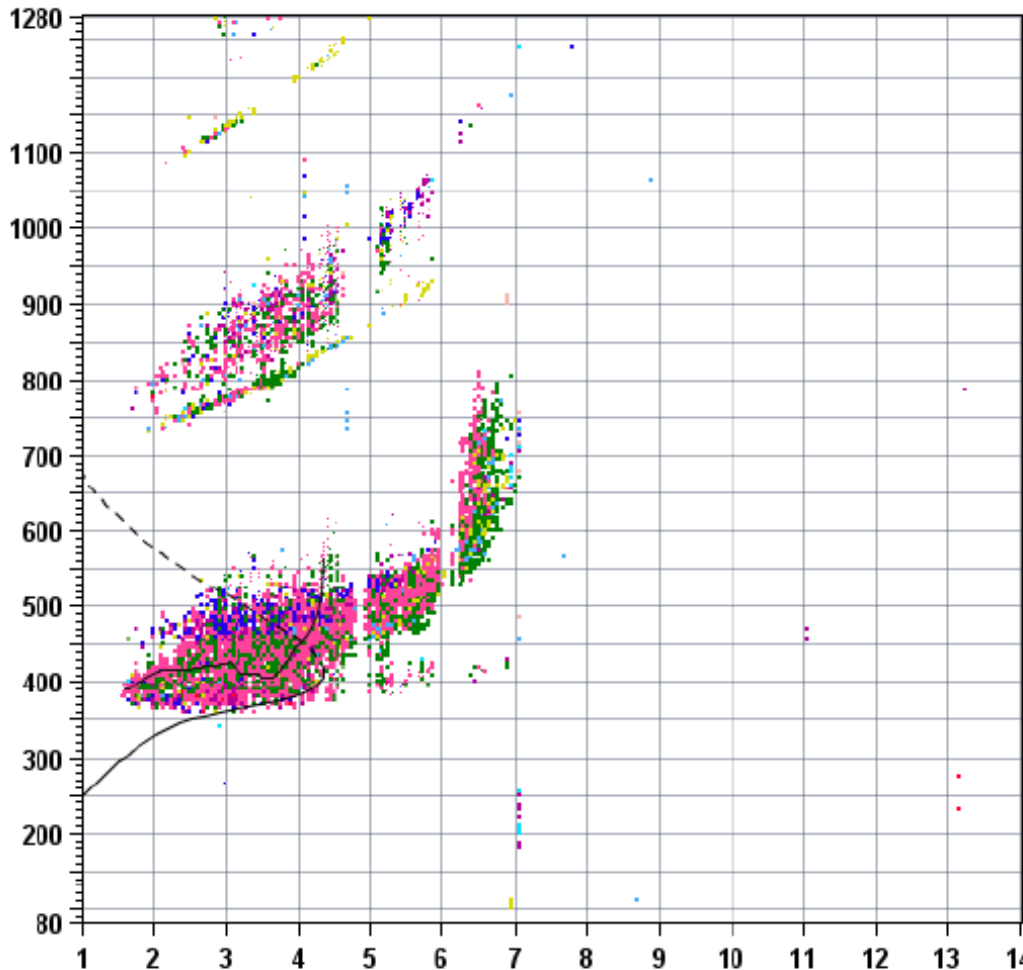
MUF(D) 11.69  
 M(D) 2.69  
 D N/A

h`F 391.5  
 h`F2 391.5  
 h`E N/A  
 h`Es N/A

hmF2 412.7  
 hmF1 N/A  
 hmE 110.0  
 yF2 72.8  
 yF1 N/A  
 yE 20.0  
 BO 50.8  
 B1 4.55

C-level 22

Auto:  
 Artist5  
 500200



- NoVal
- NNE
- E
- W
- Vo-
- Vo+
- SSW
- X-
- X+
- SSE
- NNW

Ground Sunset  
 17:56Hrs.

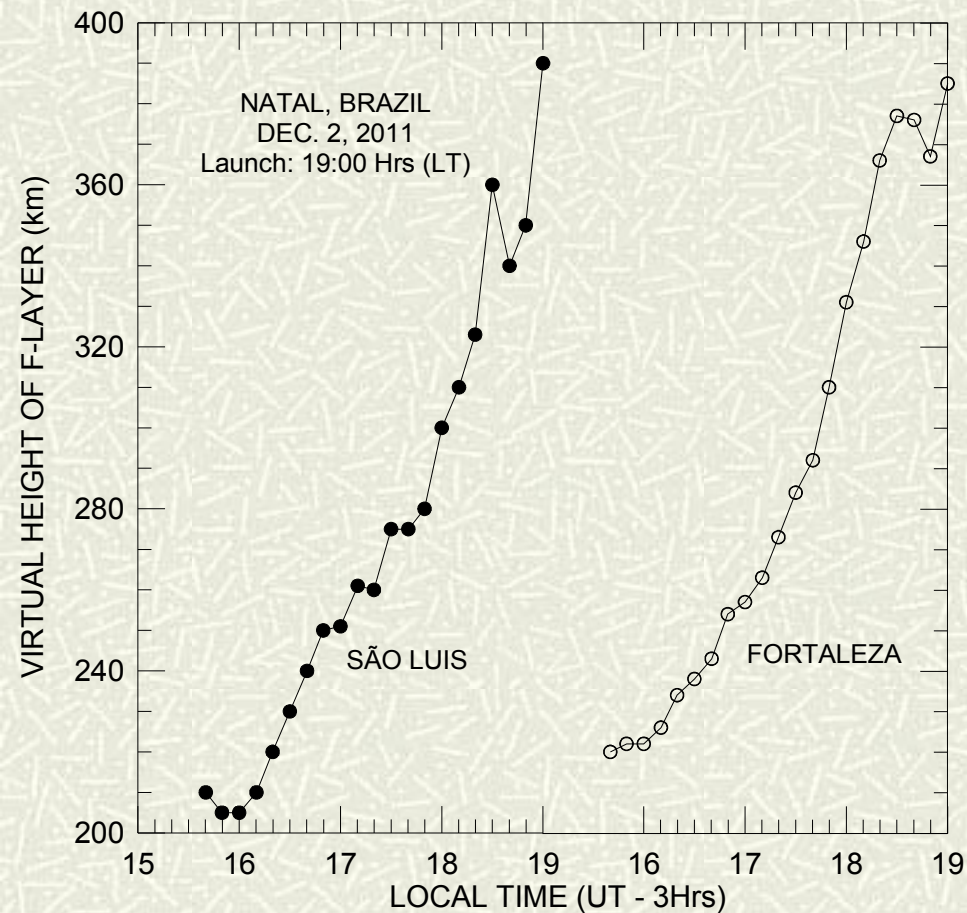
300km Sunset  
 ~19:05Hrs

D 100 200 400 600 800 1000 1500 3000 [km]  
 MUF 4.7 4.7 4.9 5.2 5.5 6.1 7.7 11.7 [MHz]

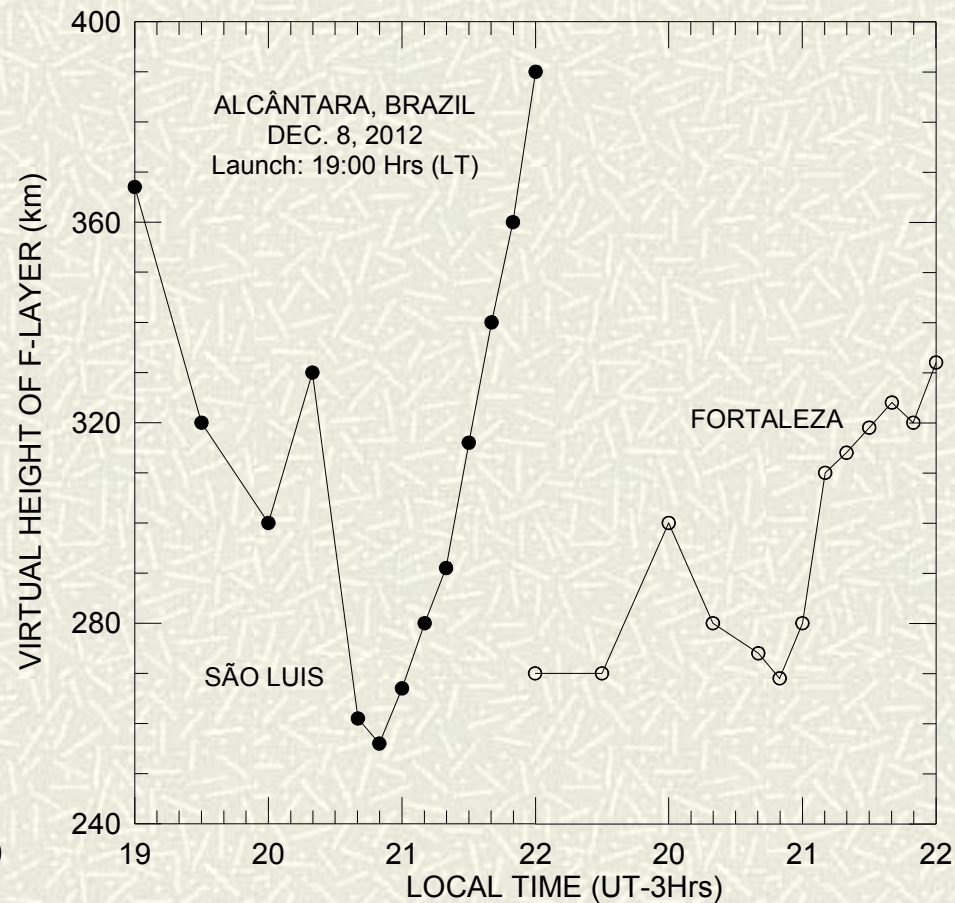




## F-Layer height variation



F-Layer velocity at São Luís and Fortaleza: 10 – 35m/s



F-Layer Velocity at São Luís and Fortaleza: Highly variable

# CONCLUSIONS



- Wave structures in electron density and temperature were not observed in the valley region during the first launch at 21:17 hours, probably because the launch occurred after the F-layer got stabilised and the PRE activity had stopped.
- Wave structures in  $n_e$  and  $T_e$  were observed in the second and third launches made at 19:00 hours. This probably is related to the fast uplift of the F-layer at the time of launch as well as with the PRE activity still at its peak.
- However in all the three cases the valley region showed abnormally large  $T_e$  values. This high temperature observed during upleg reduced to practically normal values during downleg when the plasma bubbles were observed.



- The absence of high electron temperatures in the downleg profile is probably due to the fact that the PRE activity in the region of downleg had stopped at the time of rocket descent and also the plasma bubbles had developed in that region.
- In all the three cases strong spread-F traces were present in the ionograms at the time of launch.
- Probably the high electron temperatures observed in the valley region are due to the intense wave activity and upward movement of plasma (PRE) close to sunset and the  $T_e$  values become normal once the plasma bubbles develop.



# Acknowledgements



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  - Alcântara Launch Center – CLA/MAER, Alcântara
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