MINISTÉRIO DA CIÊNCIA E TECNOLOGIA
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

CHARACTERISTICS OF THE GPS SIGNAL SCINTILLATIONS DURING IONOSPHERIC IRREGULARITIES AND THEIR EFFECTS OVER THE GPS SYSTEM

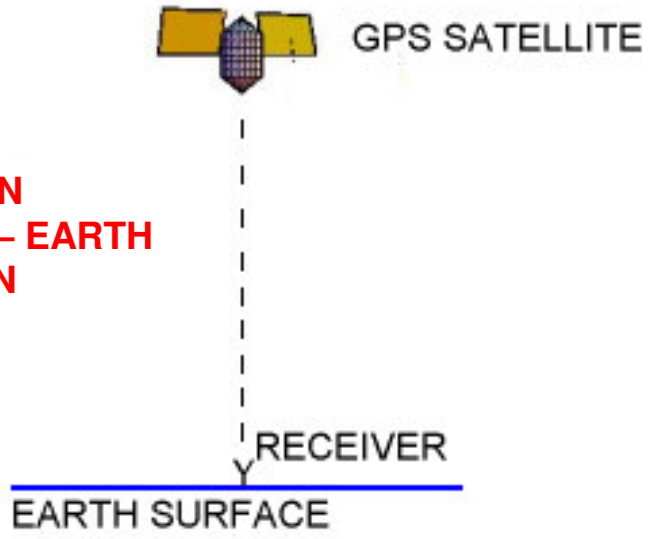
Eurico R. de Paula, I.J.Kantor, L.F.C. de Rezende

AERONOMY DIVISION – NATIONAL INSTITUTE FOR SPACE RESEARCH (INPE)

IV SIMPÓSIO BRASILEIRO DE ENGENHARIA INERCIAL

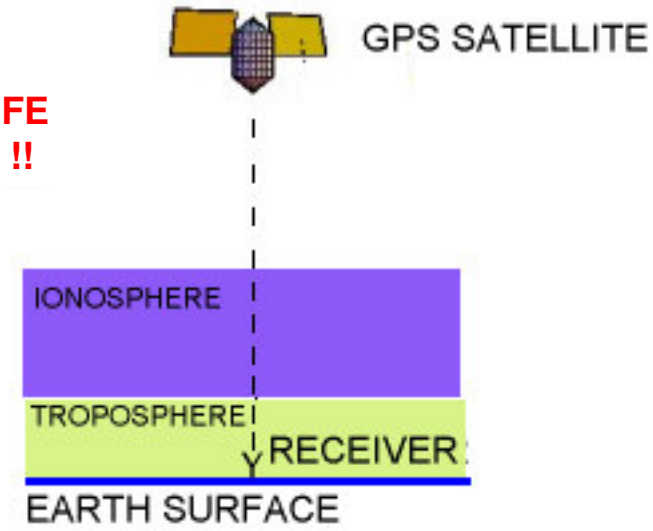
INPE – 17 – 19 DE NOVEMBRO DE 2004

IDEAL CONDITION FOR SATELLITE – EARTH COMMUNICATION



INTERFERENCES FROM ATMOSPHERIC LAYERS

HOWEVER REAL LIFE
IS NOT THAT EASY !!



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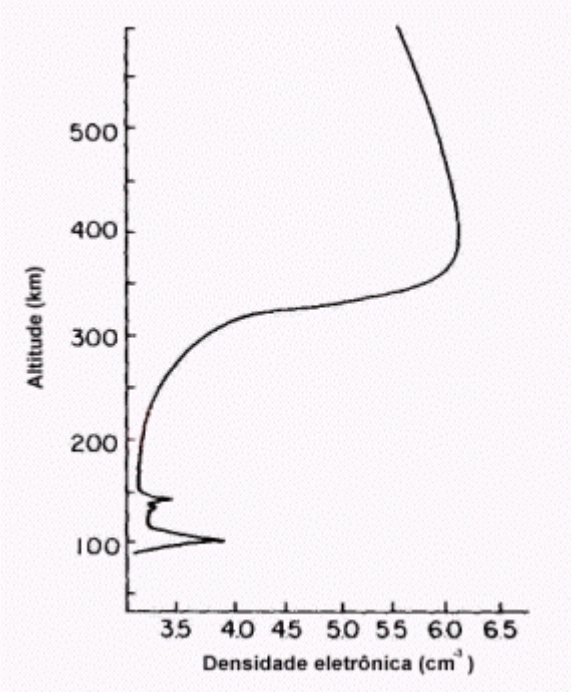
  - EFFECTS ON THE SBAS (SPACE BASED AUGMENTATION SYSTEM)
  - EFFECTS ON THE DGPS (DIFFERENTIAL GPS)

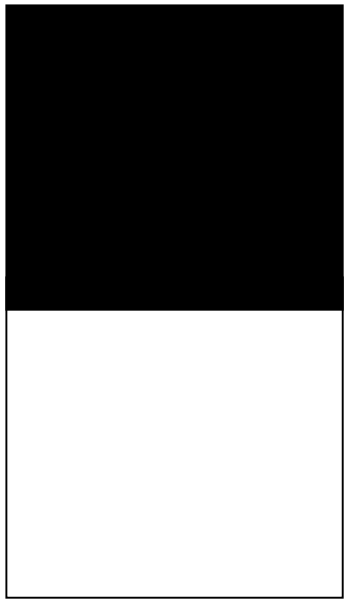
PHYSICAL MECHANISM THAT GIVE ORIGIN TO THE IONOSPHERIC IRREGULARITIES

IONOSPHERIC IRREGULARITY GENERATION MECHANISM

Rayleigh - Taylor (RT) instability Dungey (1956)



Kelley (1989, pag. e 122)



Animação gentilmente cedida
por C. M. Denardini

IONOSPHERIC IRREGULARITIES CHARACTERISTICS

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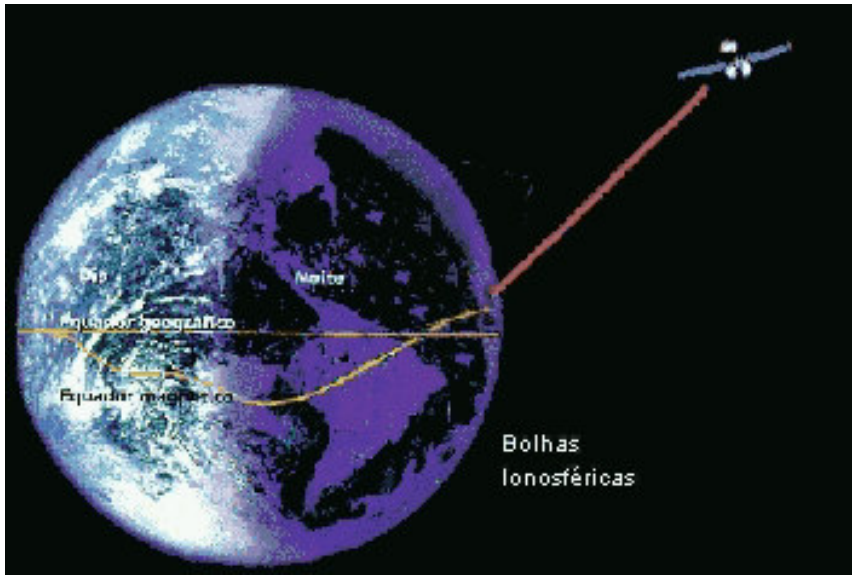
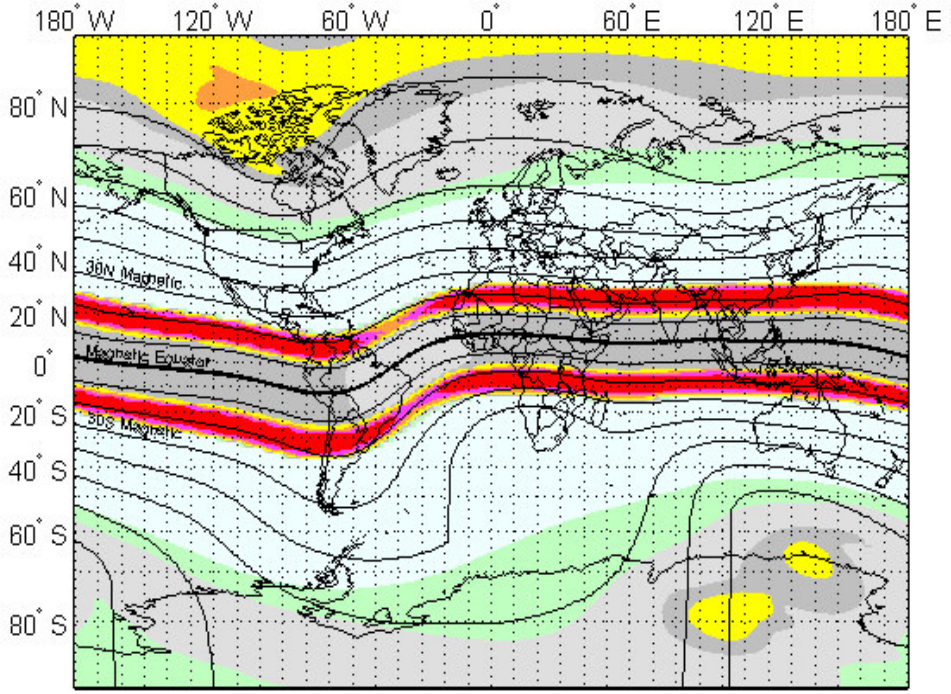


IONOSPHERIC IRREGULARITIES CHARACTERISTICS

- **THE EFFECTS ARE IN THE TROPICAL REGION ALL OVER THE WORLD WITH LARGEST INCIDENCE OVER BRAZIL (LARGE MAGNETIC DECLINATION).**



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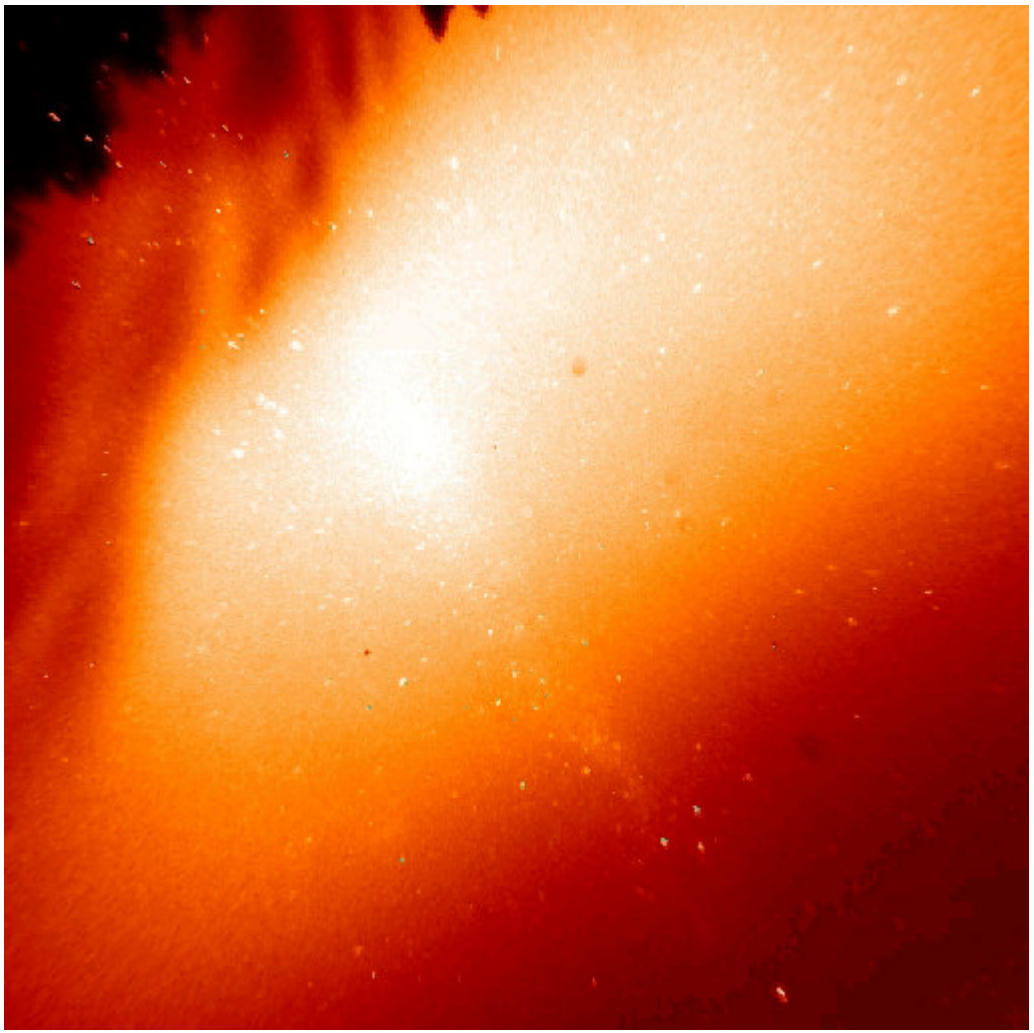
- **DURING MAGNETICALLY QUIET PERIODS THEY DRIFT FROM WEST TO EAST WITH A VELOCITY OF ABOUT 150 m / s. (SHOWED AT NEXT SLIDE).**

IONOSPHERIC IRREGULARITIES CHARACTERISTICS

BUBBLE EASTWARD DISPLACEMENT (21 – 01 LT)

N

W



E

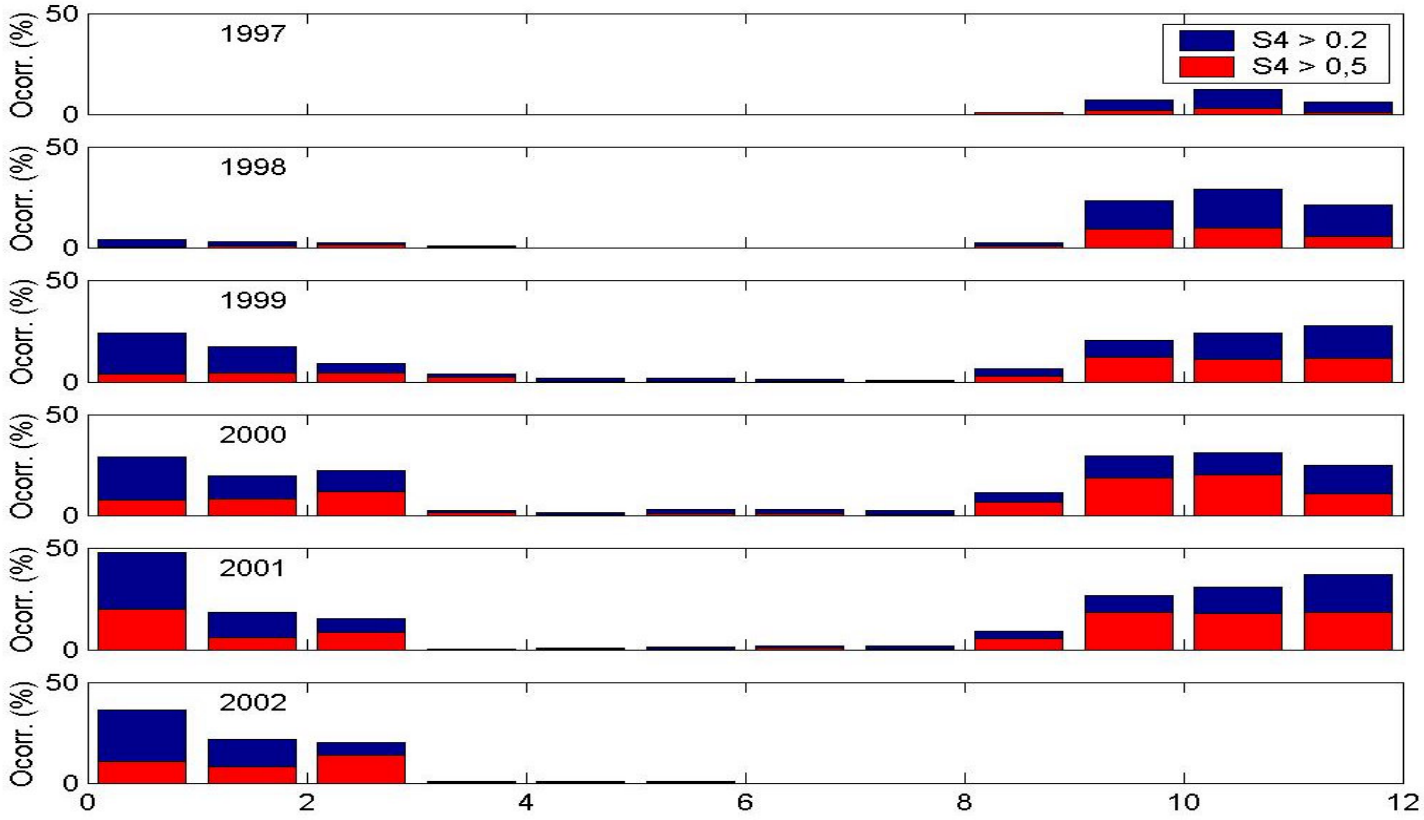
S

ALL SKY PHOTOMETER 6300 Å, MARCH 18 1999, CACHOEIRA PAULISTA.

BUBBLES ARE ELECTRON DENSITY DEPLETED REGIONS AND CONSEQUENTLY THERE IS A DRASTIC REDUCTION IN THE AEROLUMINESCENCE INTENSITY OVER THESE REGIONS.

DEPENDENCE OF IONOSPHERIC IRREGULARITIES WITH LOCAL TIME

SEASONAL EFFECTS



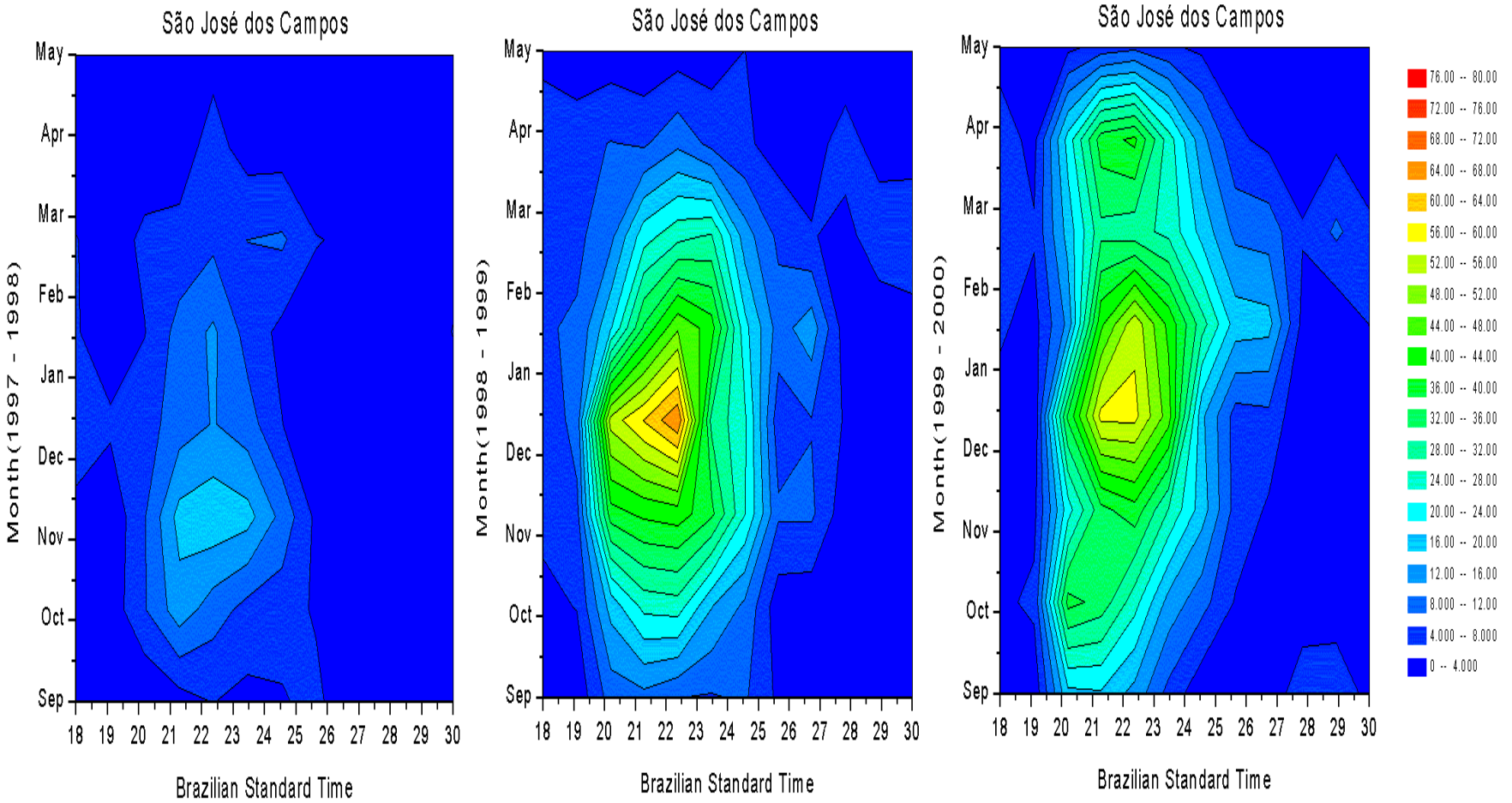
IONOSPHERIC IRREGULARITIES OCCURRENCES FROM SEPTEMBER TO MARCH

DEPENDENCE OF IONOSPHERIC IRREGULARITIES WITH LOCAL TIME AND SOLAR ACTIVITY

F10.7=96 1997-1998

F10.7=134 1998-1999

F10.7=173 1999-2000



Occurrence of L-band scintillation versus time and month for three years of increasing solar activity.

DEPENDENCE OF IONOSPHERIC IRREGULARITIES WITH MAGNETIC ACTIVITY

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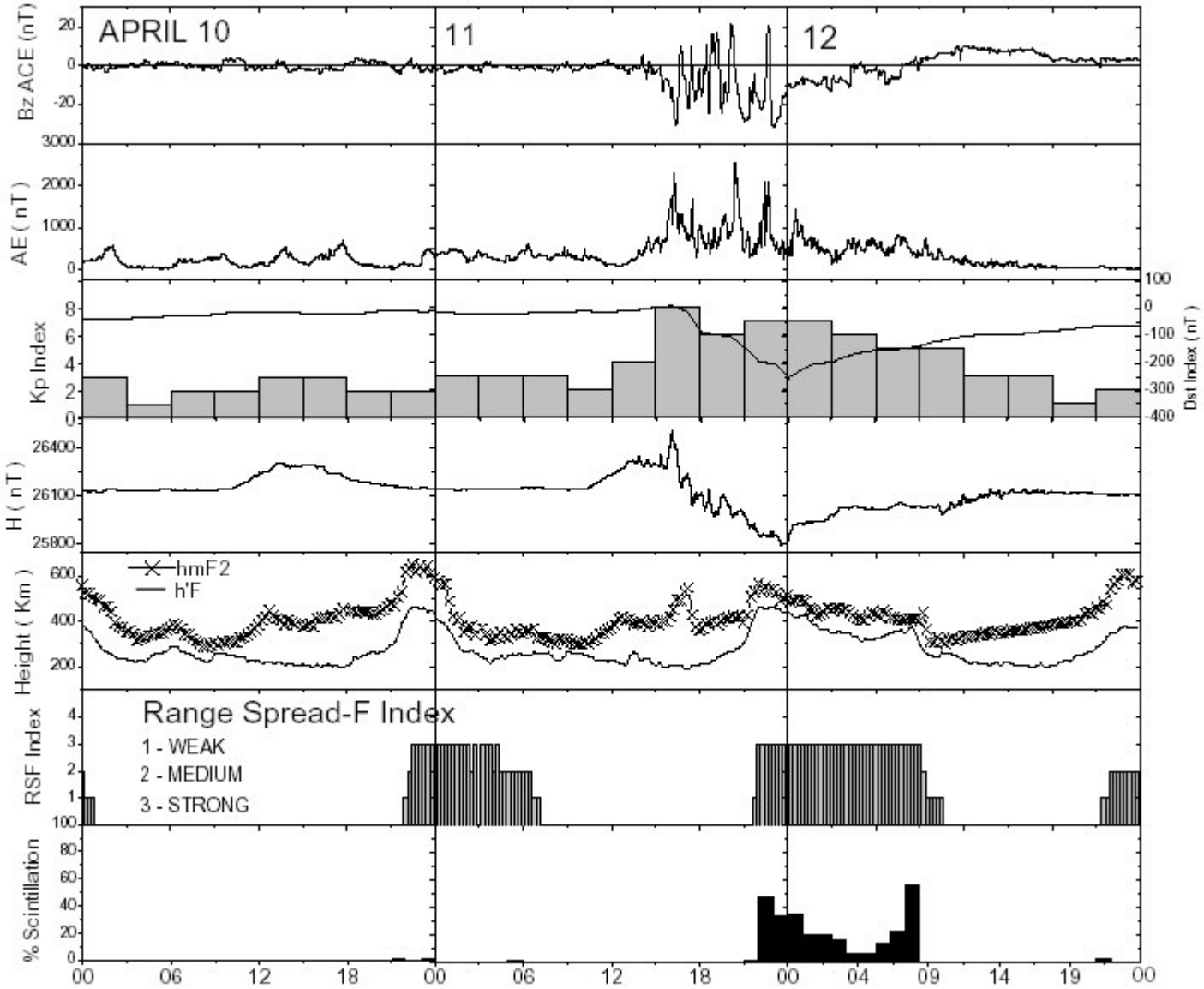
- **OTHERWISE THE MAGNETIC STORM CAN TRIGGER IRREGULARITIES AT ANY MONTH OF THE YEAR (EVEN DURING PERIOD OF NON OCCURRENCE). ONE EXAMPLE FOLLOWS AT NEXT SLIDE:**

DEPENDENCE OF IONOSPHERIC IRREGULARITIES WITH MAGNETIC ACTIVITY



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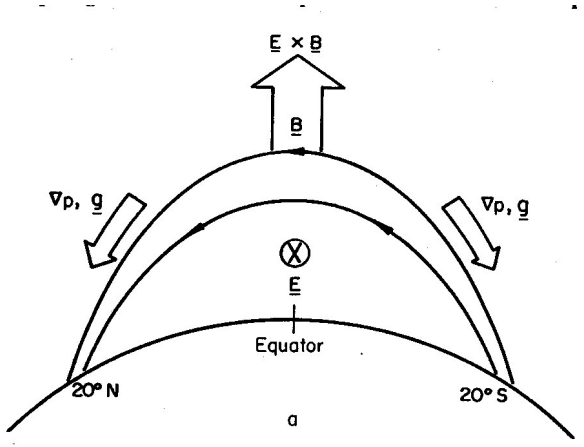

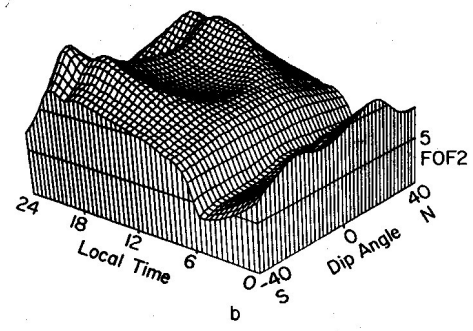

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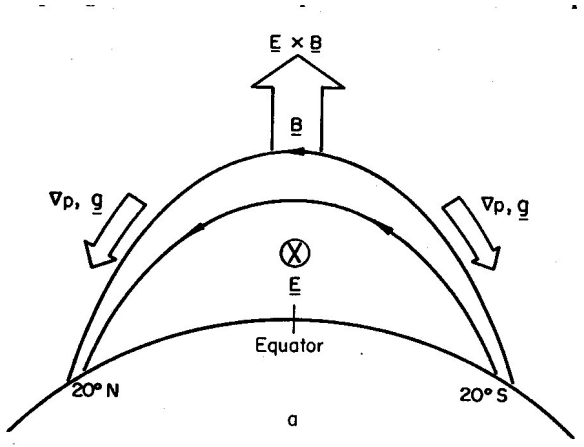
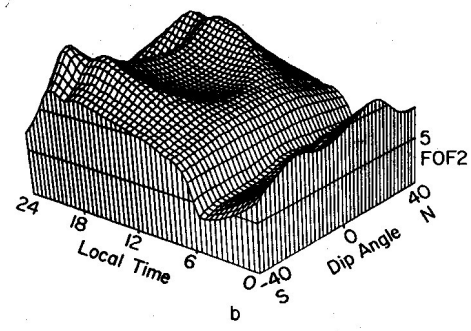
- THE EARTH IONOSPHERE, THAT IS AN IONIZED ATMOSPHERIC LAYER, CAUSES A DELAY IN THE GPS SIGNAL THAT PROPAGATES WITH THE GROUP VELOCITY (V_g) THAT IS SMALL THAN LIGHT VELOCITY.





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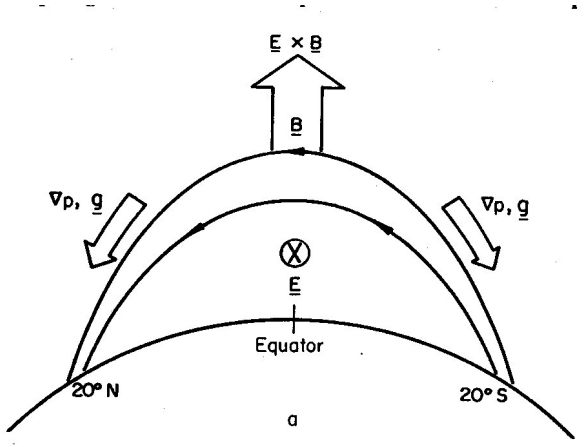
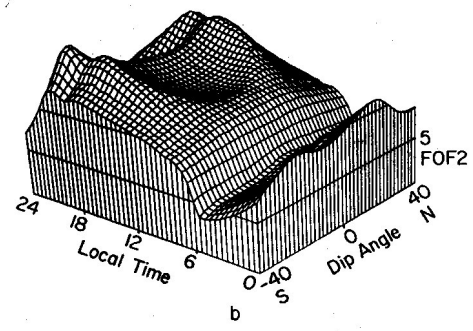
- **THIS IONOSPHERIC DELAY IS PROPORTIONAL TO THE TOTAL ELECTRON CONTENT ALONG THE GPS SIGNAL.**





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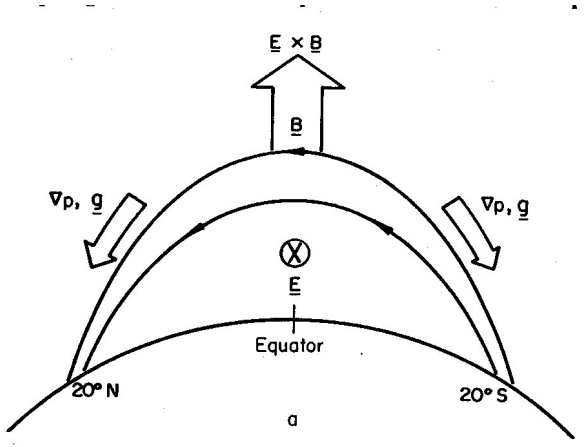

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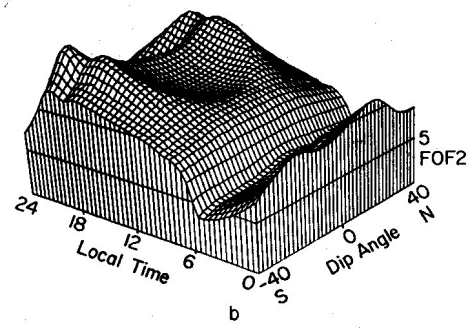
- **OVER LOW MAGNETIC LATITUDES (BRAZIL FOR EXAMPLE) THE IONOSPHERE PRESENTS THE EQUATORIAL IONOSPHERIC ANOMALY THAT CONSTITUTES OF HIGHER ELECTRON DENSITIES PEAKS AT ABOUT 15 MAGNETIC DEGREES (NORTH AND SOUTH) COMPARED TO EQUATORIAL REGION.**



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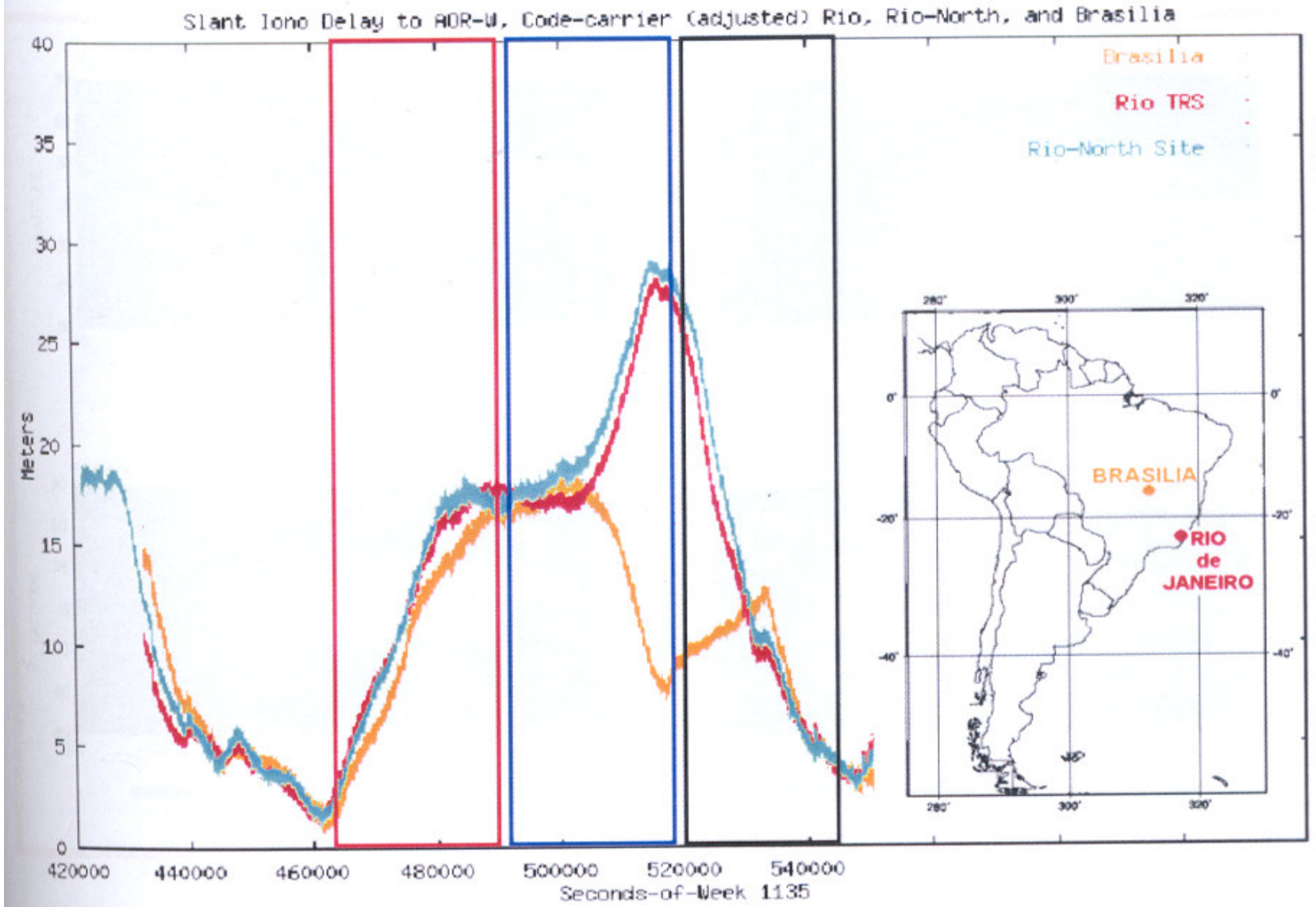

PLOT FROM TOM DEHEL (FAA – FEDERAL AVIATION ADMINISTRATION – USA), 2002

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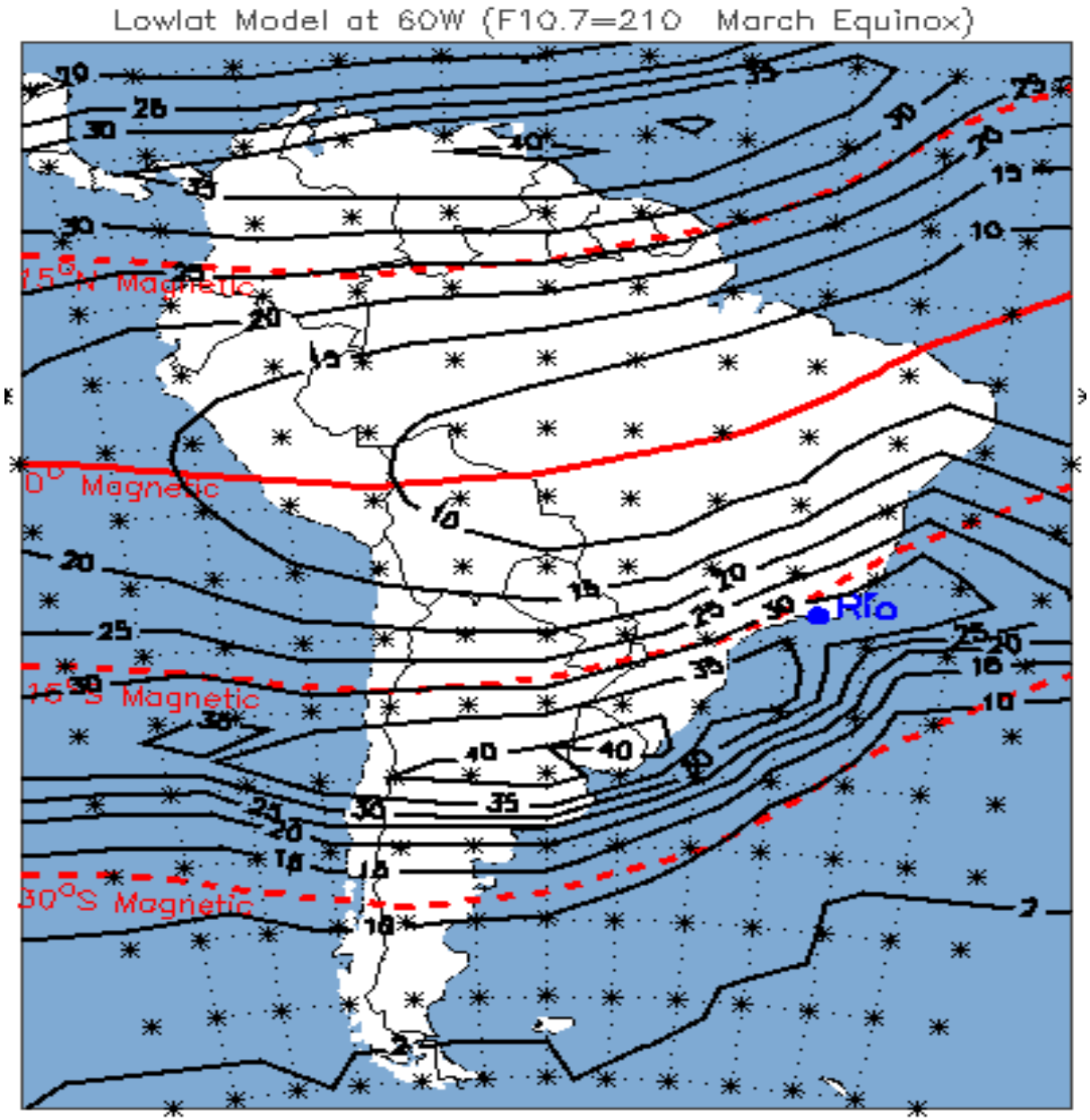
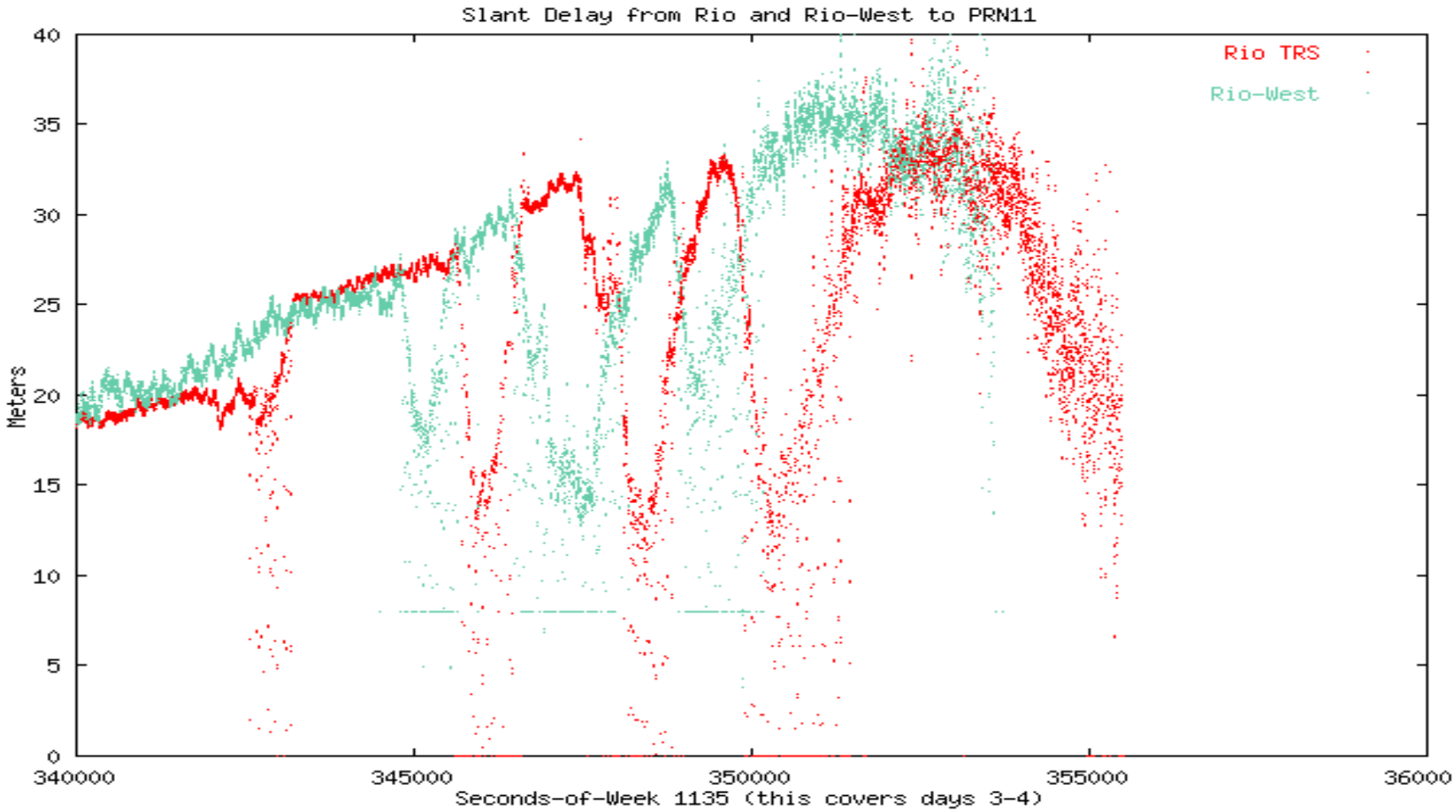


THE EFFECTS OF IONOSPHERIC IRREGULARITIES OVER TEC

- **IONOSPHERIC IRREGULARITIES CAUSE LARGE DEPLETION ON THE TOTAL ELECTRON CONTENT.**



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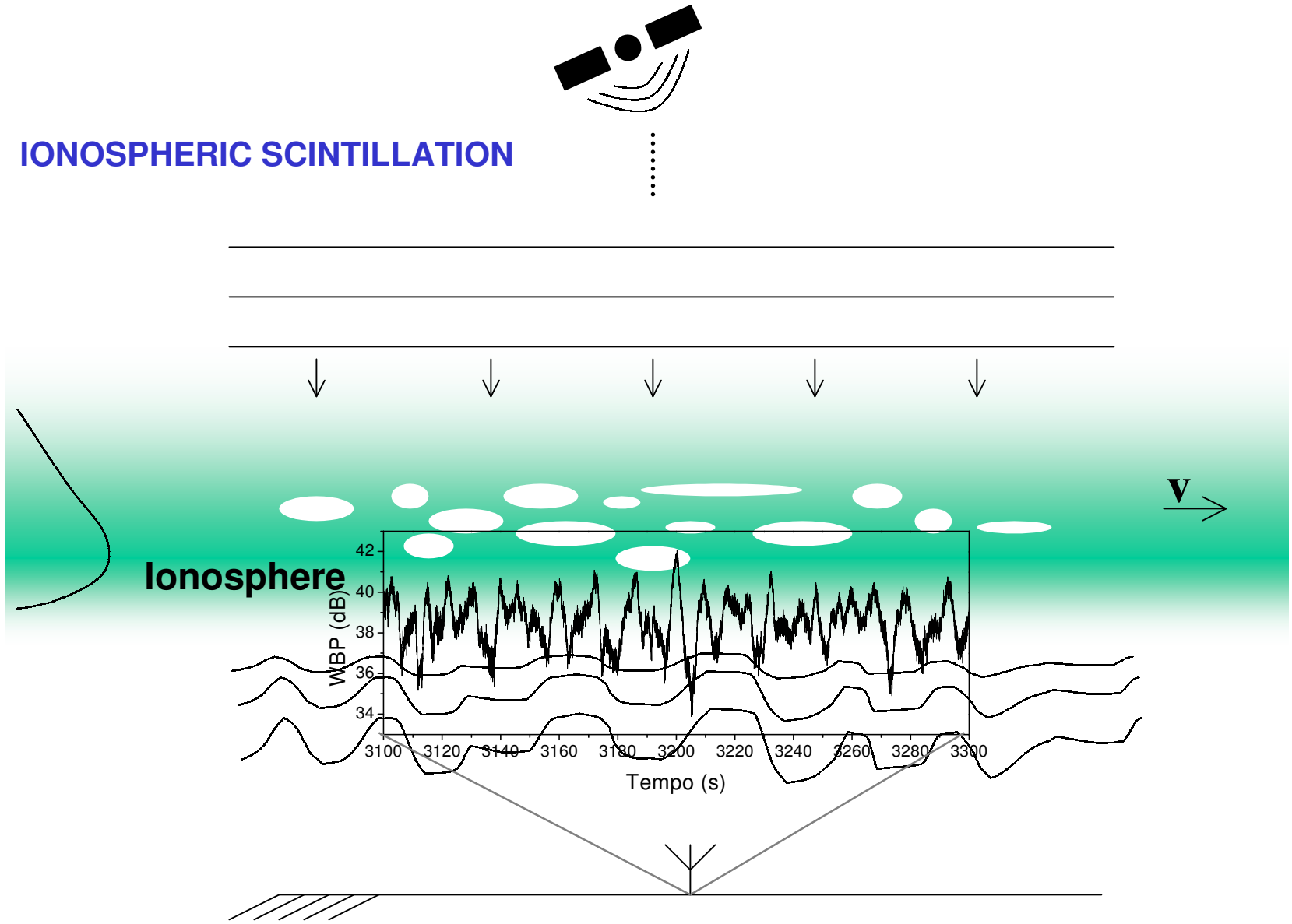
POTENTIAL EFFECTS OF SCINTILLATIONS ON GPS CAUSED BY IONOSPHERIC IRREGULARITIES

IONOSPHERIC SCINTILLATION



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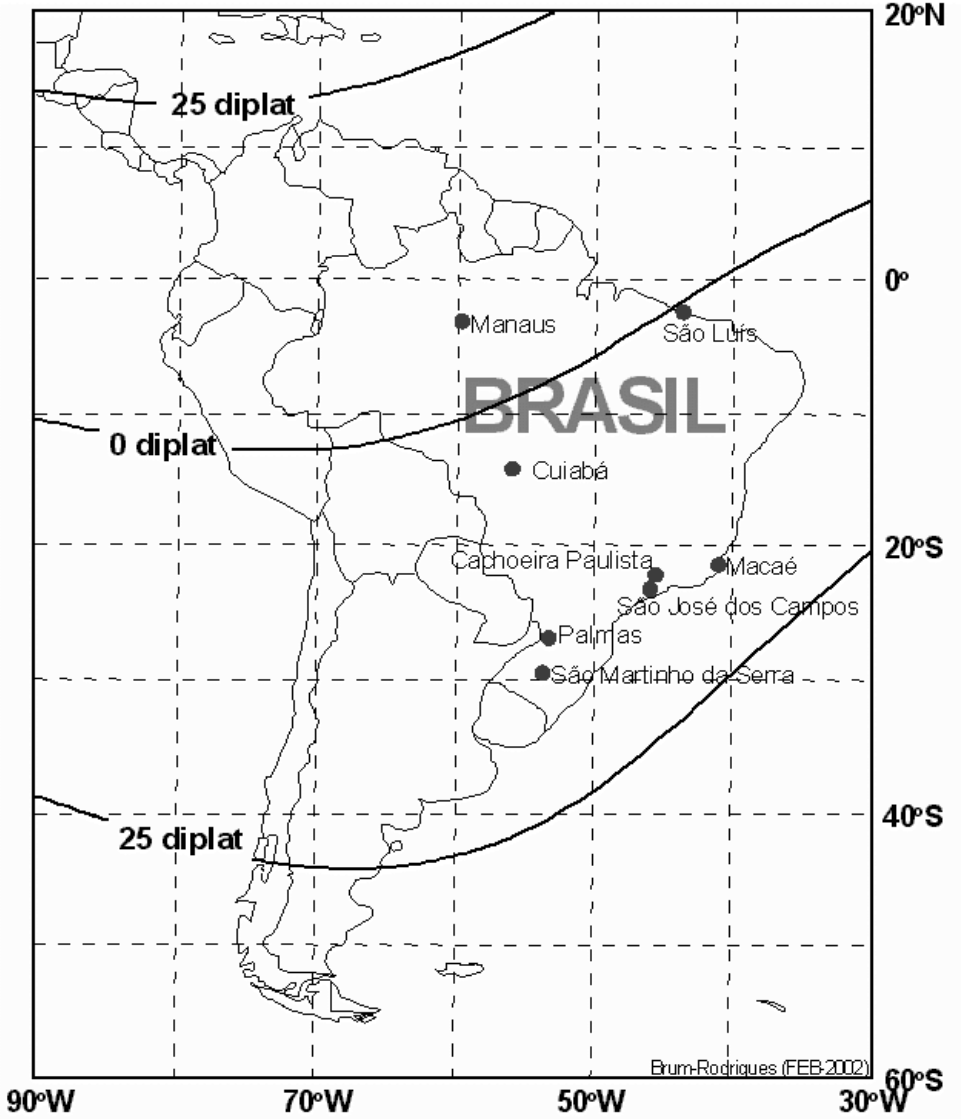
SCINTMON RECEIVERS SITES OVER BRAZIL



POTENTIAL EFFECTS OF SCINTILLATIONS ON GPS CAUSED BY IONOSPHERIC IRREGULARITIES

TO ANALYSE THE GPS SCINTILLATIONS OVER BRAZIL, WE USE AN ARRAY OF 12 SCINTILLATION MONITORS (L1 BAND AT 1.575 GHz) LOCATED AT 8 SITES.

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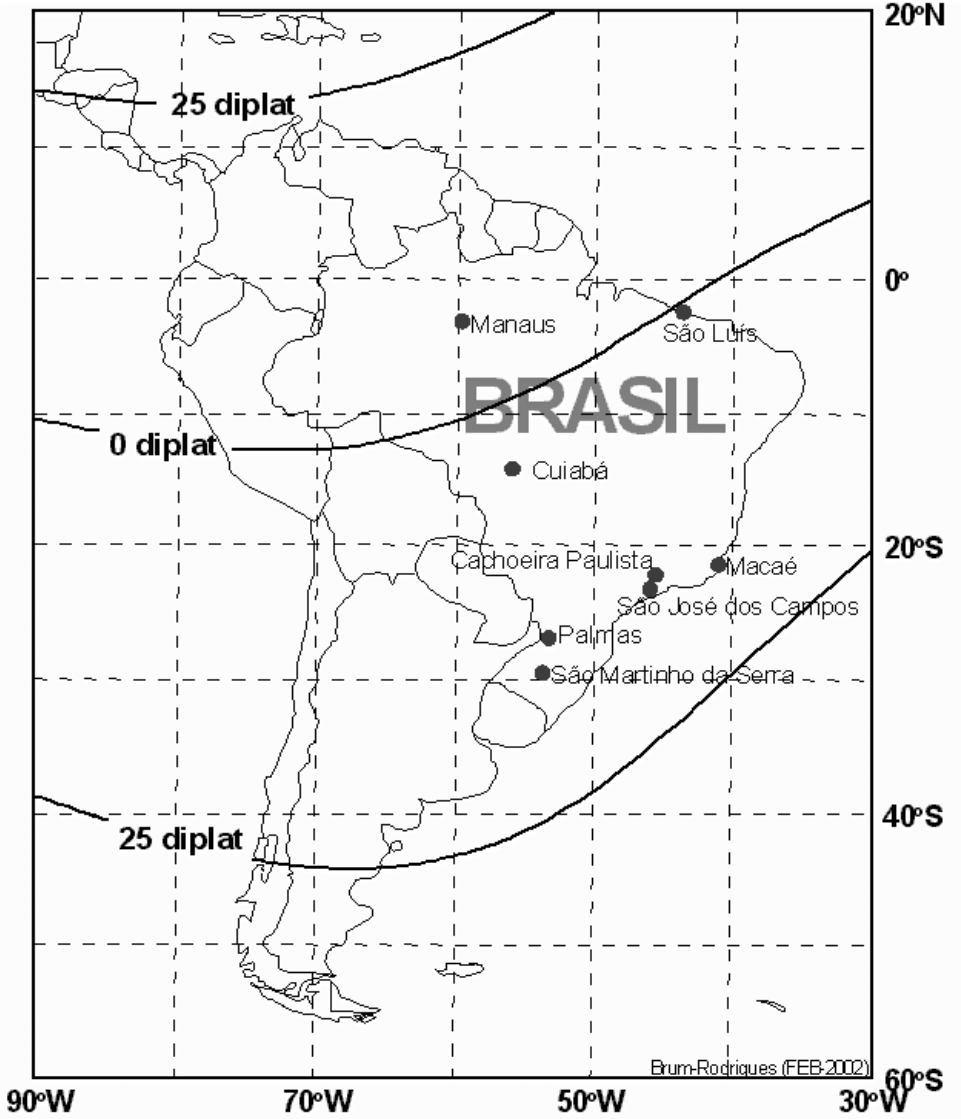

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TO QUANTIFY THE AMPLITUDE SCINTILLATION, WE USE THE S4 INDEX THAT IS THE STANDARD DEVIATION OF THE SIGNAL INTENSITY RELATIVE TO THE AVERAGE CALCULATED AT EACH MINUTE:

$$S_4^2 = \frac{< I^2 > - < I >^2}{< I >^2}$$

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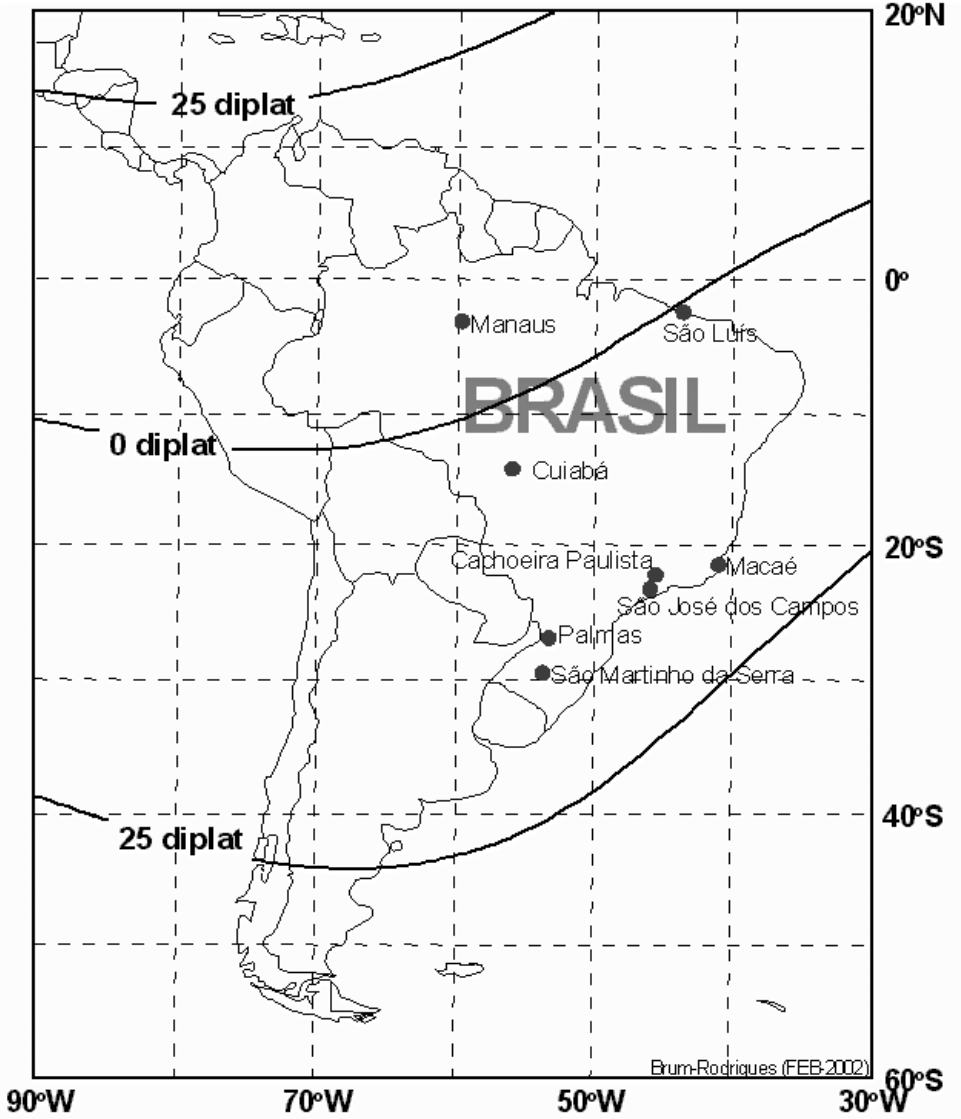
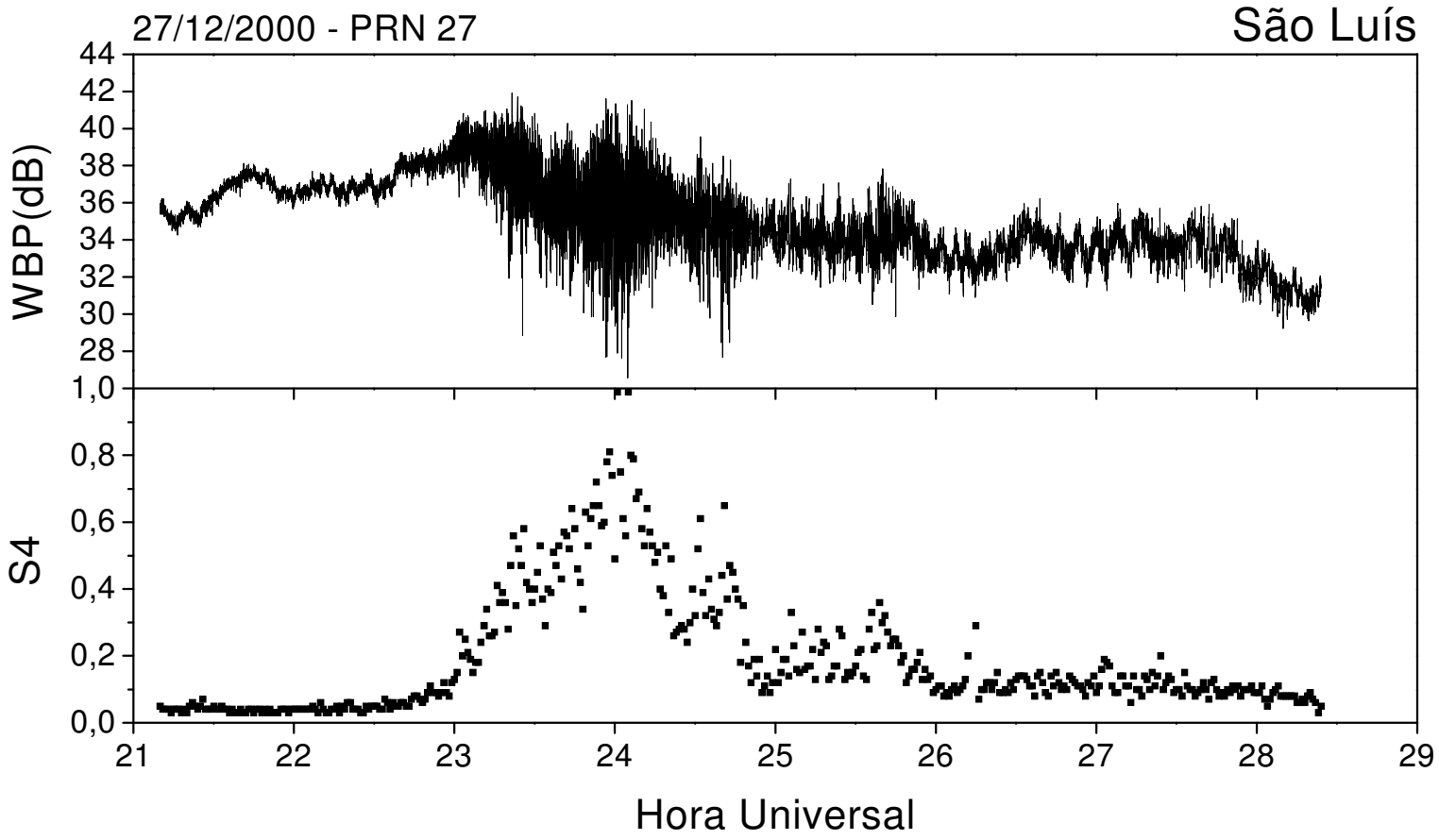


POTENTIAL EFFECTS OF SCINTILLATIONS ON GPS CAUSED BY IONOSPHERIC IRREGULARITIES

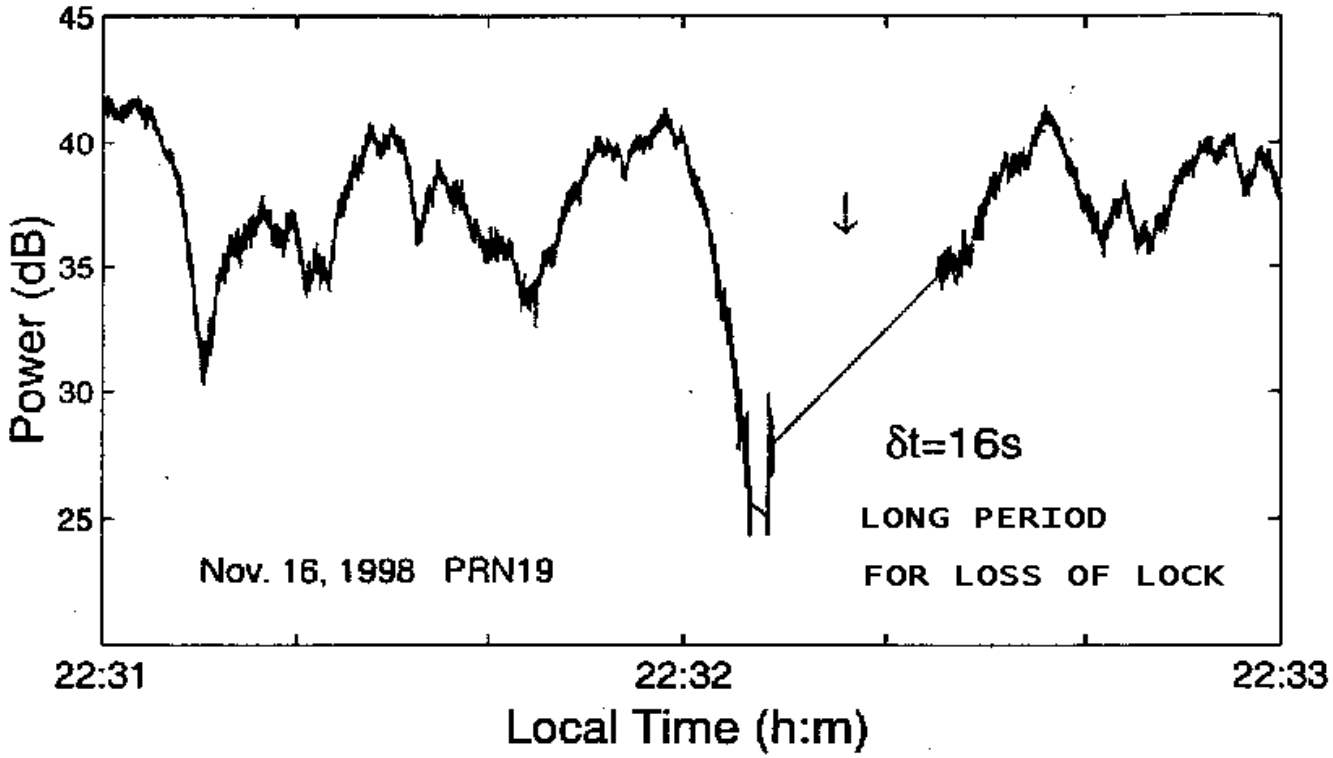
EXAMPLE OF GPS IONOSPHERIC SCINTILLATION:



POTENTIAL EFFECTS OF SCINTILLATIONS ON GPS CAUSED BY IONOSPHERIC IRREGULARITIES

LOSS OF LOCK

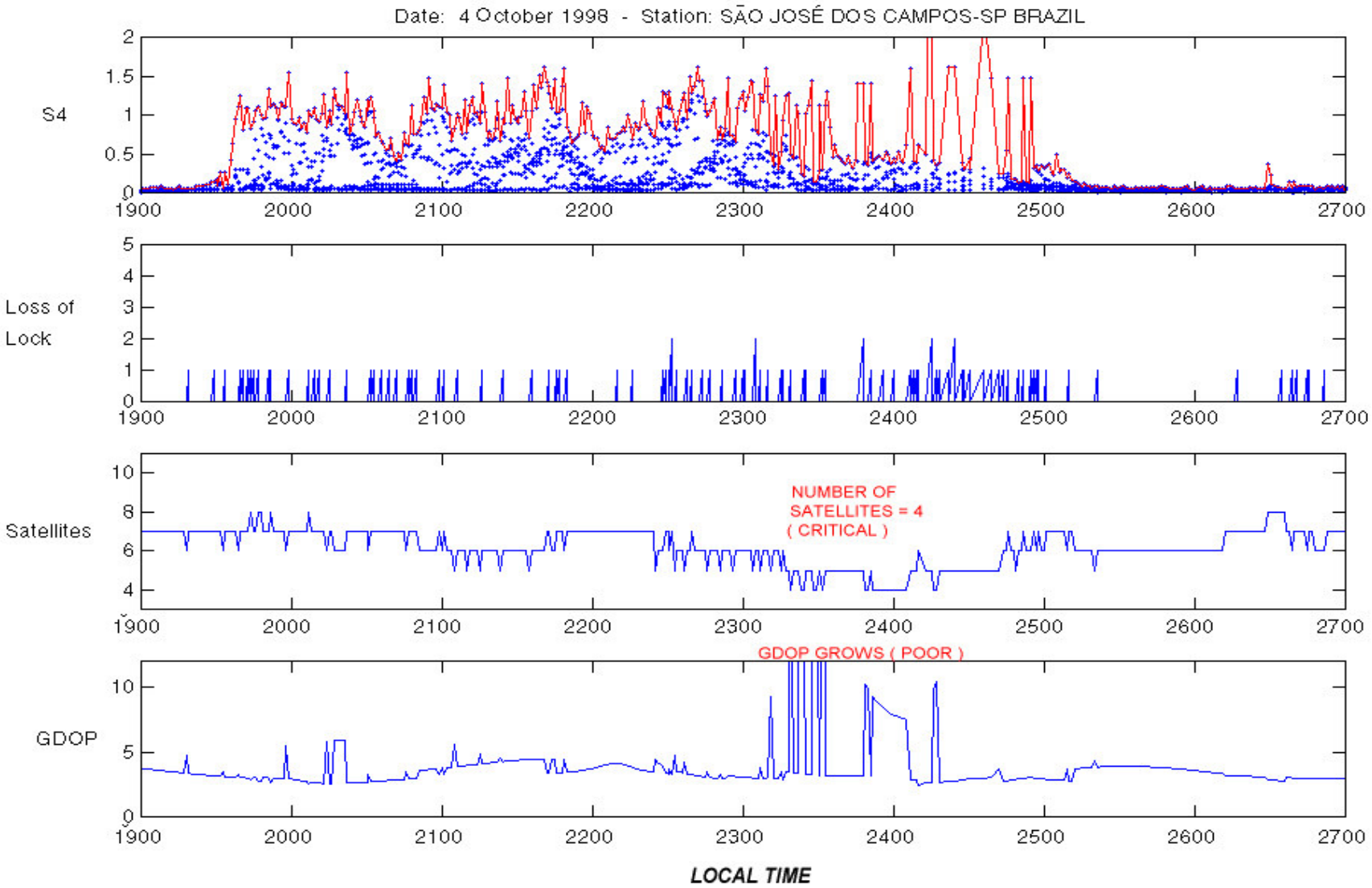
•Navigation and positionig information are affected during loss of lock.



Source: Paul Kintner et al.: GPS FADING TIMESCALES AND CONSEQUENCES, Radio Science, 2001

POTENTIAL EFFECTS OF SCINTILLATIONS ON GPS CAUSED BY IONOSPHERIC IRREGULARITIES

DILUTION OF PRECISION INCREASE (DEGRADATION) AND DECREASE ON AVAILABLE NUMBER OF GPS SATELLITES



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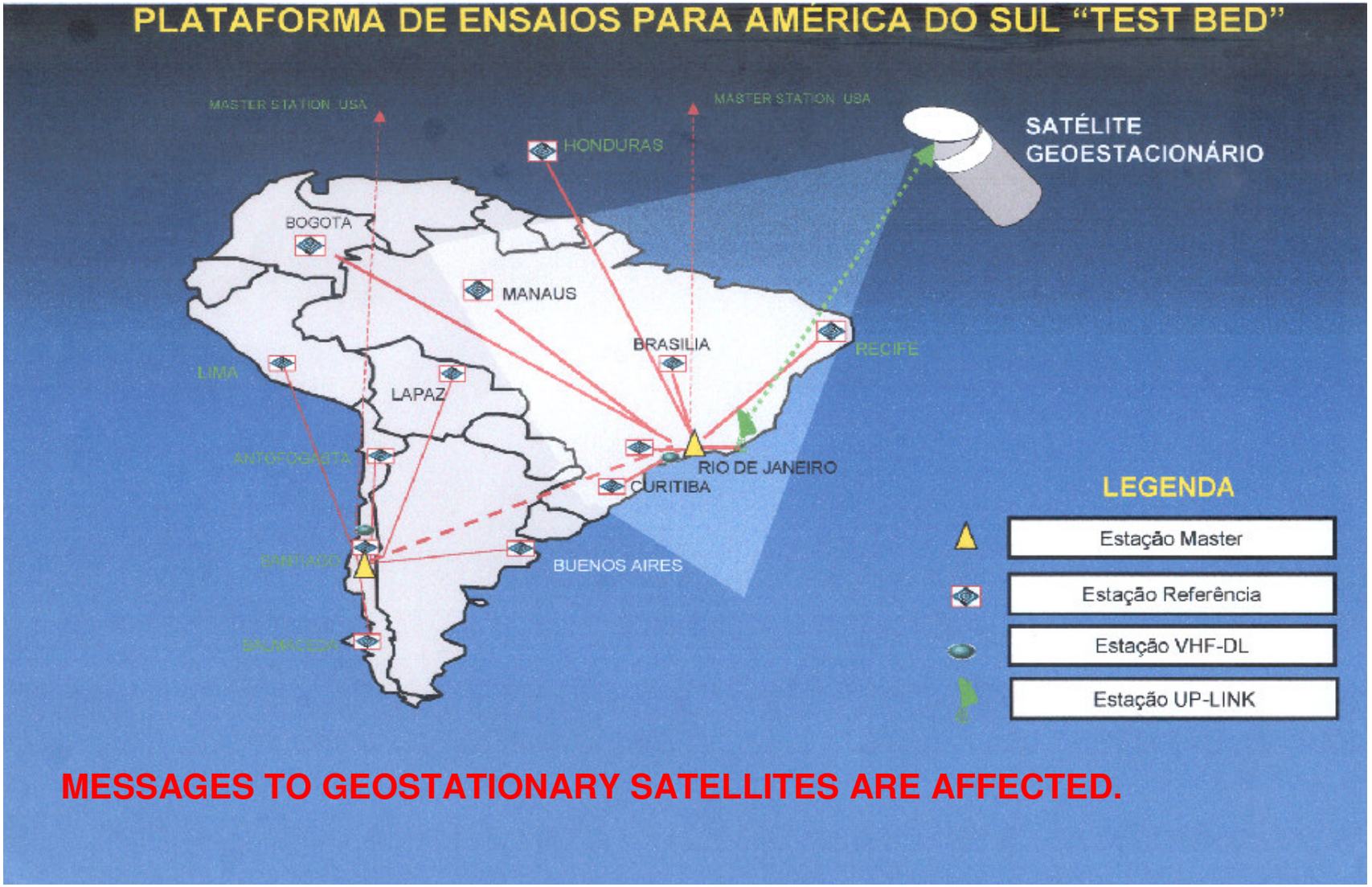
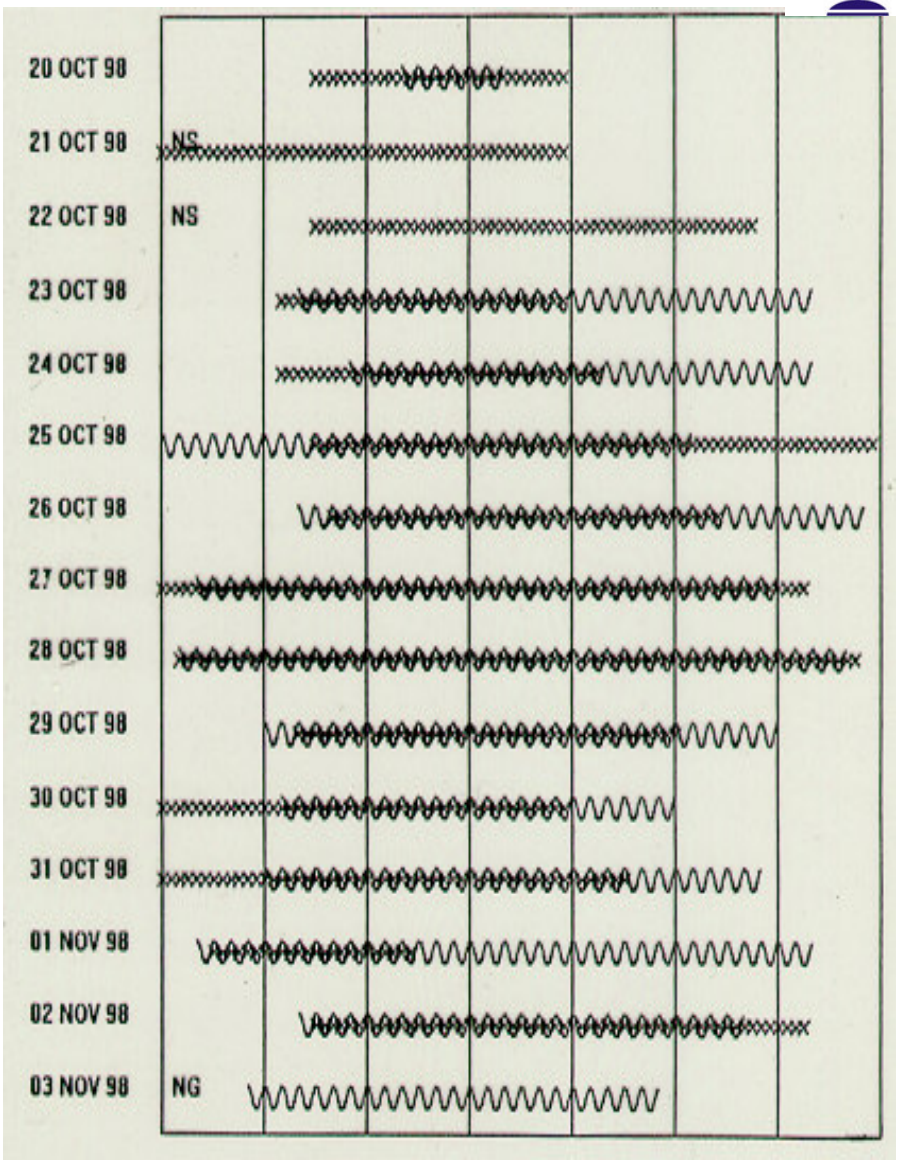
EFFECTS ON THE SBAS (SPACE BASED AUGMENTATION SYSTEM)



MESSAGES TO GEOSTATIONARY SATELLITES ARE AFFECTED.

POTENTIAL EFFECTS OF SCINTILLATIONS ON GPS CAUSED BY IONOSPHERIC IRREGULARITIES

EFFECTS ON THE DGPS (DIFFERENTIAL GPS)



= IONOSPHERIC SCINTILLATION AT SJ CAMPOS

XXXX = NOC DGPS IN PETROBRÁS DYNAMIC POSITION VESSELS PERFORMING DEEP WATER PETROLEUM EXPLORATION AT CAMPOS BASIN (RJ)

(IN MARSAT L BAND SIGNAL PROBLEMS DUE TO IONOSPHERIC IRREGULARITIES)

SUGGESTIONS TO IMPROVE THE GPS PERFORMANCE DUE TO:

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TOTAL ELECTRON CONTENT (WITHOUT SCINTILLATIONS)

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TO INCREASE THE NUMBER OF AVAILABLE SATELLITES (GALILEO)

TO BUILD MORE ROBUST RECEIVERS, DECREASING THE BANDWIDTH OF GPS CARD (HOWEVER THIS PROCEDURE CAUSE INCREASE THE NUMBER OF LOSS OF LOCK).