Workshop RBMC, São Paulo, 19/06/20132012

Mapeamento do TEC América do Sul usando RBMC e outros redes de recepção GNSS

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Equatorial Ionosphere TECMAP

Contents

- How to get TEC from ground-based GPS measurements,
- Equatorial Anomaly,
- Evening Plasma enhancement,
- Plasma bubbles monitored by TEC,
- Conclusion.

How to get TEC (Total Electron Content) from groundbased GPS Receivers ?

Phase delay in the ionosphere

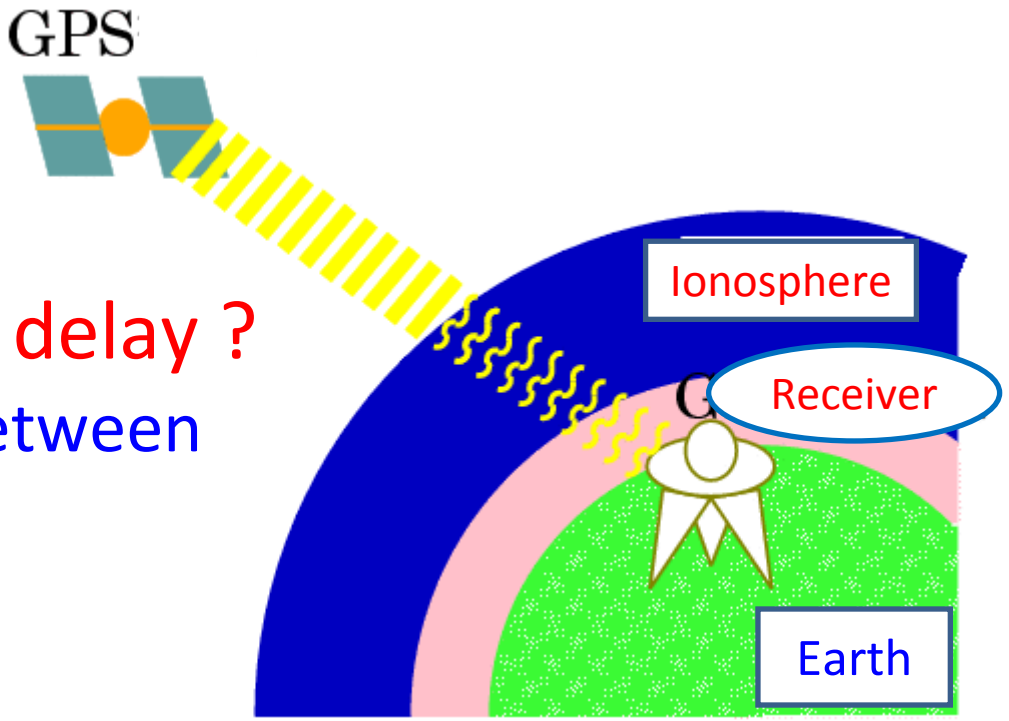
$$d\Phi = \frac{40.3 * TEC}{f^2} \text{ [m]}$$

$d\Phi$: Phase delay in [m]

TEC: TEC unit in 10^{16} eletrons/m2 col.

f: wave frequency in [cycles)

1 TECU: $d\Phi \sim 0.16$ m



How to get the phase delay ?

Using path difference between the wave 1 and wave 2

How to get TEC ?

Using path difference between the wave 1 and wave 2

1. Using Pseudo range difference from CODE

$TECp = 9.52(P_2 - P_1) + A,\ [m]$ (noisy but absolute)

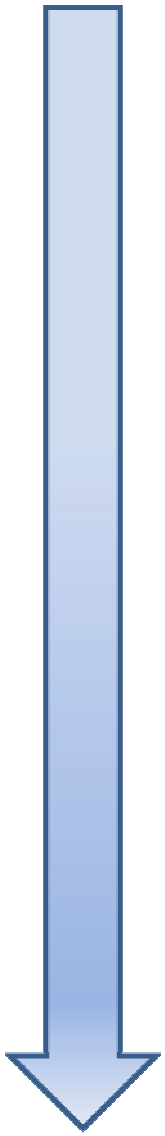
,where $P_{1,2}$ are pseudo distance of wave 1 and 2, A is instrumental factors.

2. Using a phase difference of carrier wave 1 and wave 2 and taking a factor of ambiguity B*

$TEC_\Phi = 9.52\{(\Phi_1 - \Phi_2) - B^*\} + A,\ [m]$

,where $\Phi_{1,2} = L1/f_{1,2} * c$ in [m], where c: light velocity in [m]

TEC calculation Procedure



	Start	
1	GPS data in RINEX Format	
2	Time series of CODE: P1 and P2 (Pseudorange in [m])	
3	Time series of Phase values: L1 and L2 (wave numbers)	
4	Difference of pseudorange: Dr = P2−P1 [m]	
5	Difference of L1 and L2: Dp = (L1/f1−L2/f2)*c c:light velocity	
6	Ambiguity: B=Dp−Dr for each time series	
7	Bavg: using > 1 hour of time series	
8	Slant TEC: Tr = F*(Dp − Bavg)	F=9.52
9	Instrumental Bias: Bi for each site/satellite	
10	Absolute Slant TEC: Ta= Tr + Bi	
11	Elevation angle: θ from Navigation data	
12	Vertical TEC: Tva= Sθ*Ta	Sθ: geometrical factor
	END	

GPS Groundbased receiver network by IBGE(RBMC)

IBGE RBMC Network sites

- Number of site: ~80
- Temporal resolution: 10 minutes

Estações estabelecidas (coordenadas aproximadas)

* Desativada
** Substituída

Cidade	UF	Sigla	Código SAT	Lat.	Long.	Desc.	Hist.
Altamira	PA	PAAT	99510	-3º 12'	-52º 10'		
Araçatuba	SP	SPAR	99540	-21º 11'	-50º 26'		
Arapiraca	AL	ALAR	93237	-9º 44'	-36º 39'		

example

http://www.ibge.gov.br/home/geociencias/geodesia/rbmc/rbmc_est.shtm

TEC map obtained by RBMC RINEX Data

Date: 2012. 07.11, 00:00 UT

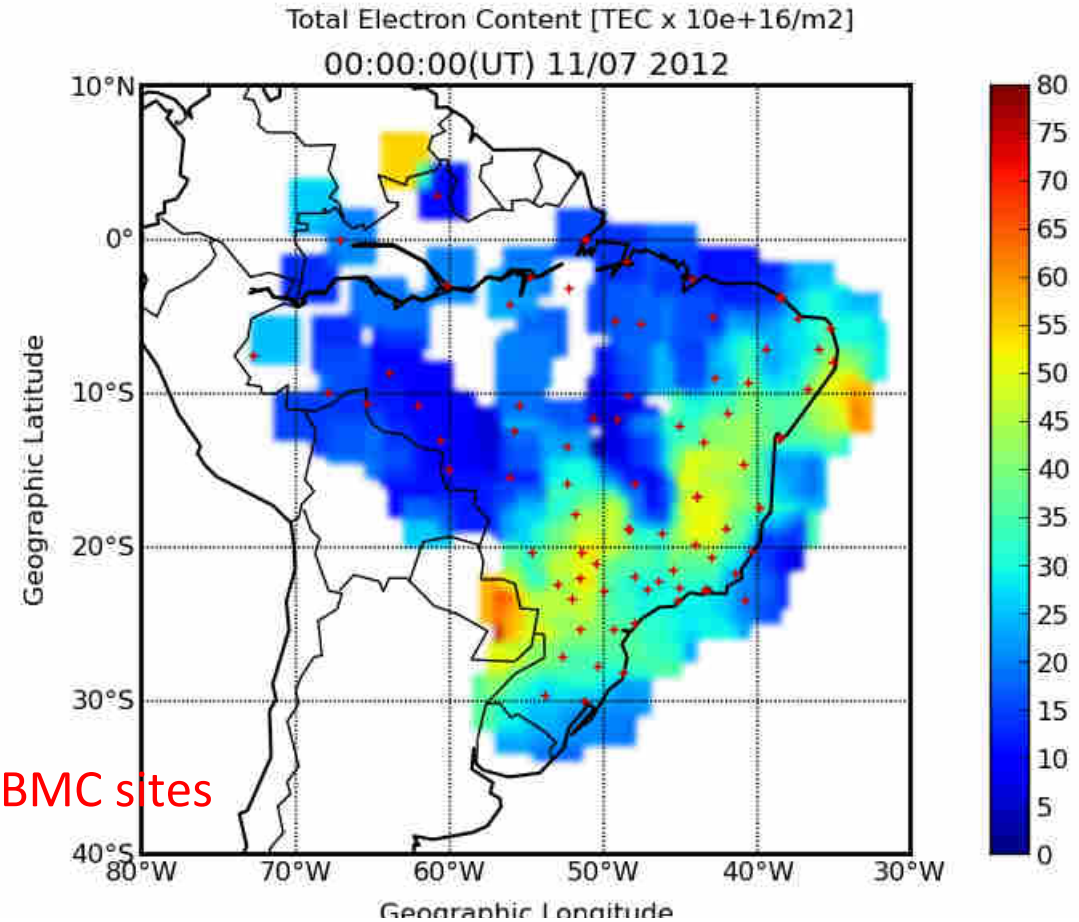
Spatial resolution:

55 – 380 km

Dependent on the density of observation points (one element: 0.5 deg. (55 km squ.))

Temporal resolution of map:

10 minutes



Red plots: RBMC sites

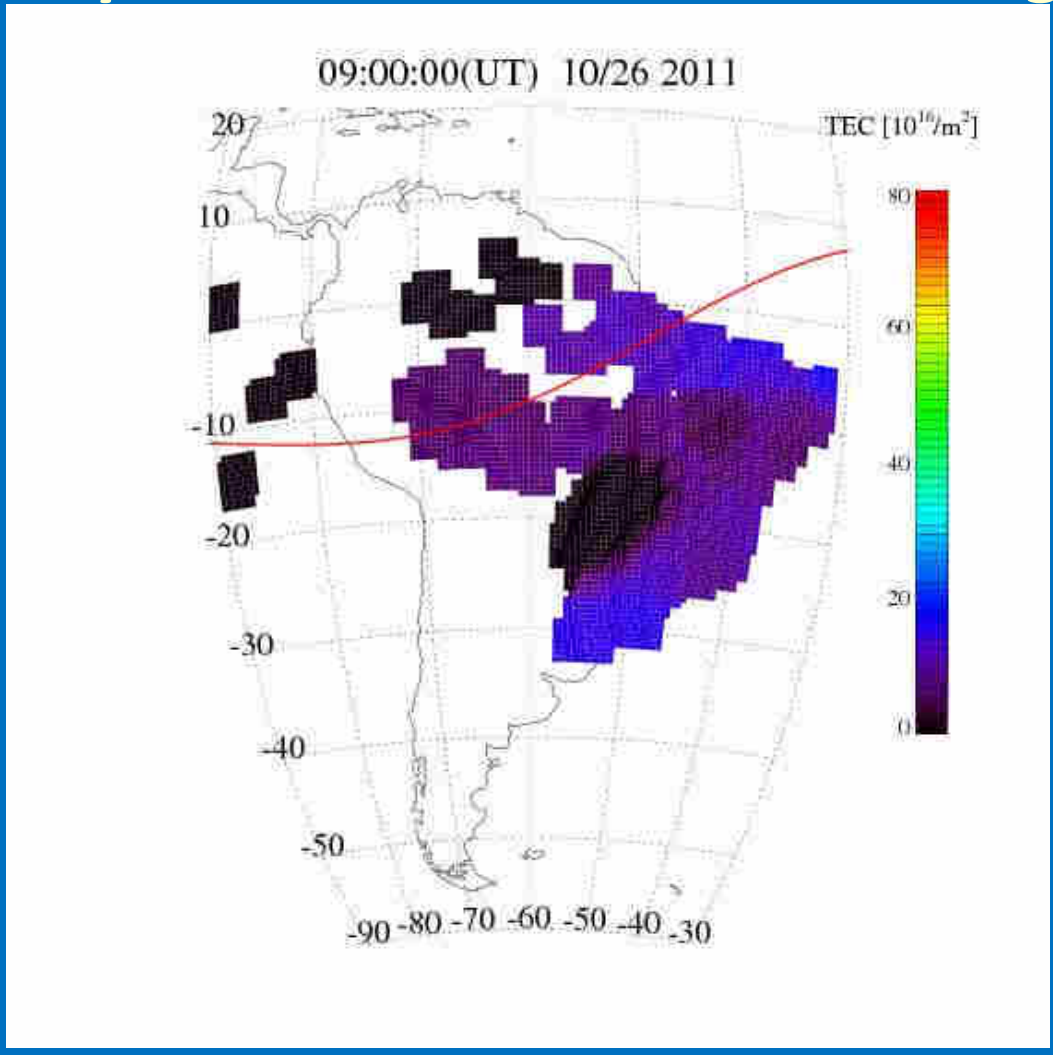
IBGE RINEX data file

TEC Mapping code: by STEL Nagoya University (Y. Otsuka)

GPSTEC Mapping: 24 hours Ionospheric Weather Monitoring

video

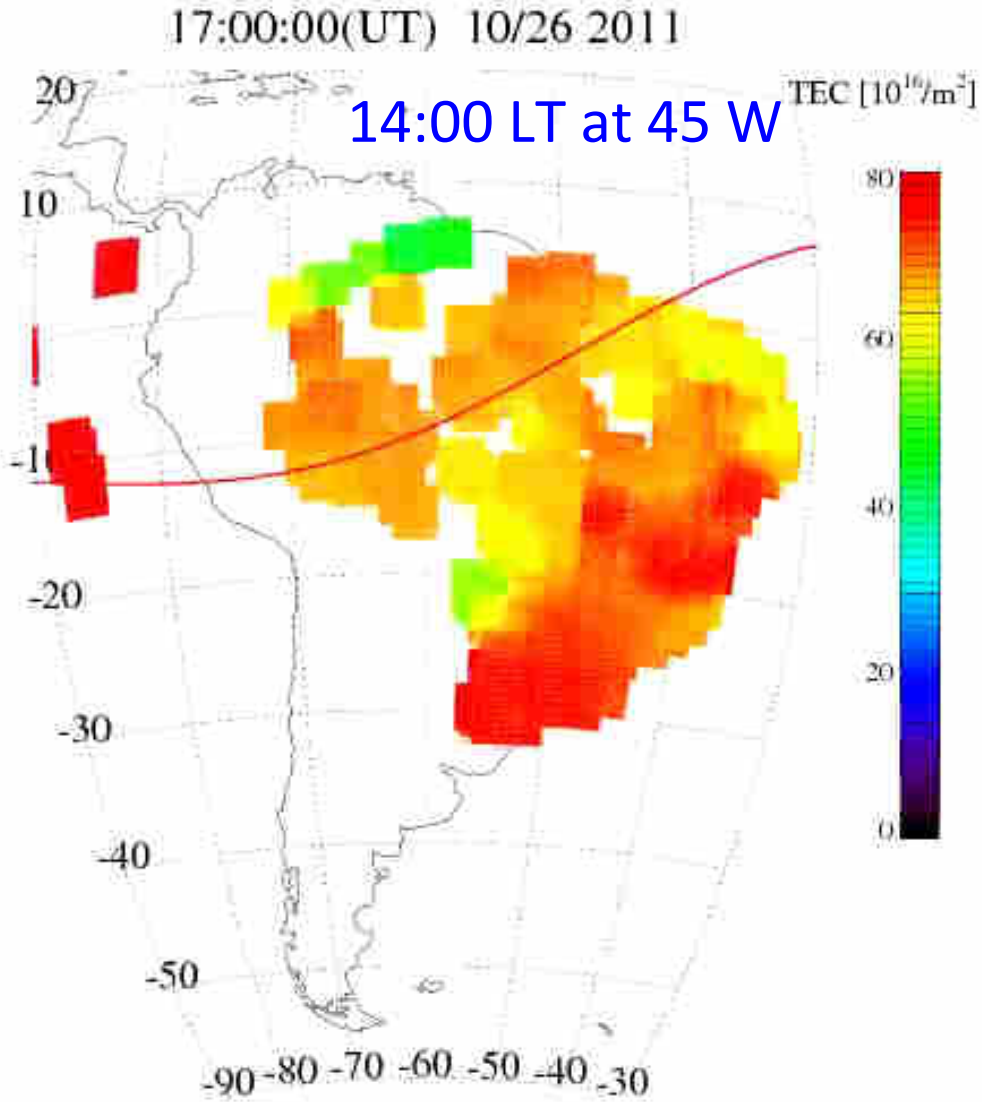
2011 Oct. 26: 6 AM to 27: 6AM (24 hours)



IBGE RINEX data file
TEC Mapping code by STEL Nagoya University (Y. Otsuka)

Equatorial Anomaly observed by GPSTEC

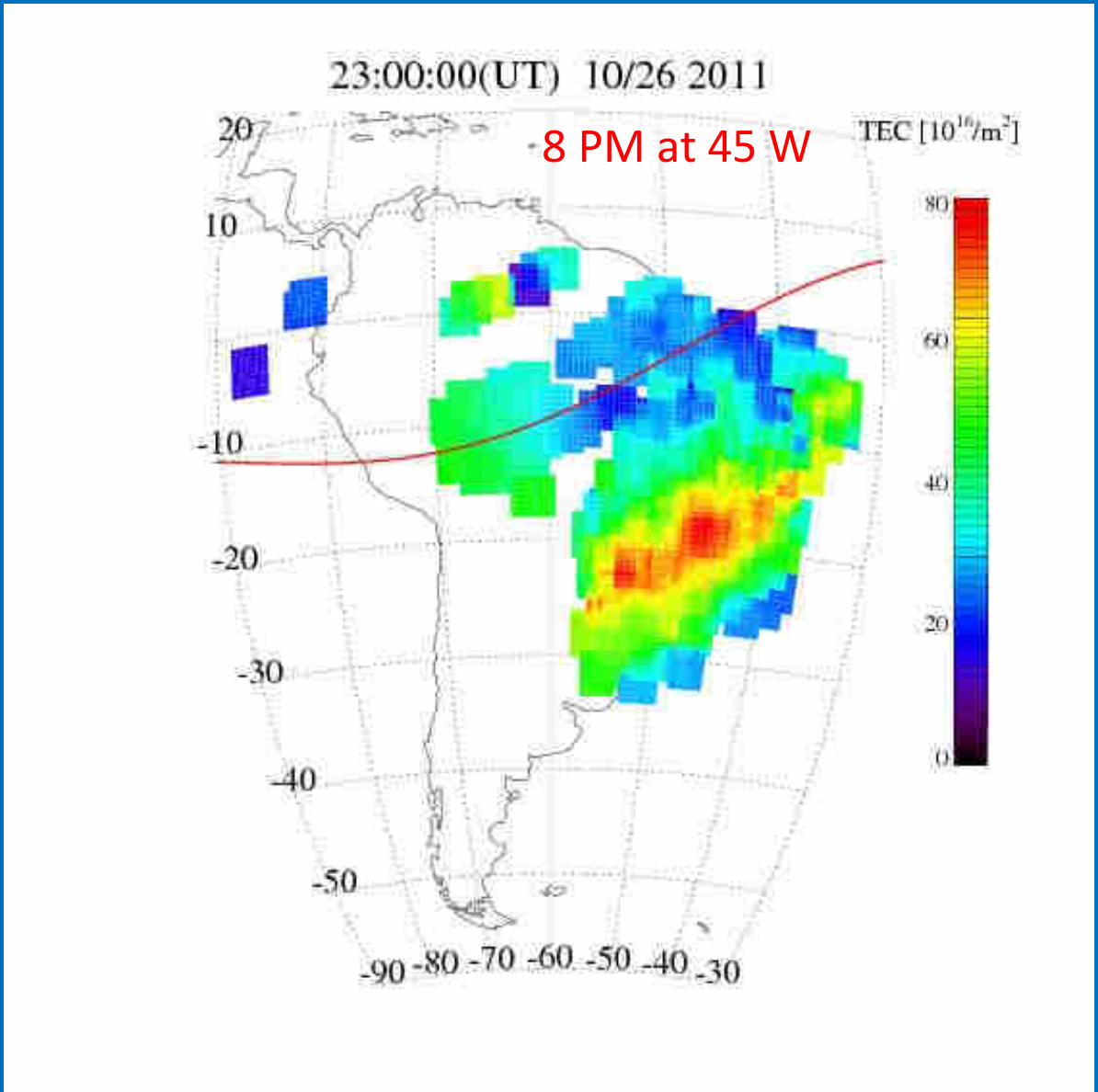
Equatorial Anomaly



Typical example at 14:00 LT

Evening Plasma Enhancements observed by GPSTEC

Evening Plasma enhancement: Example

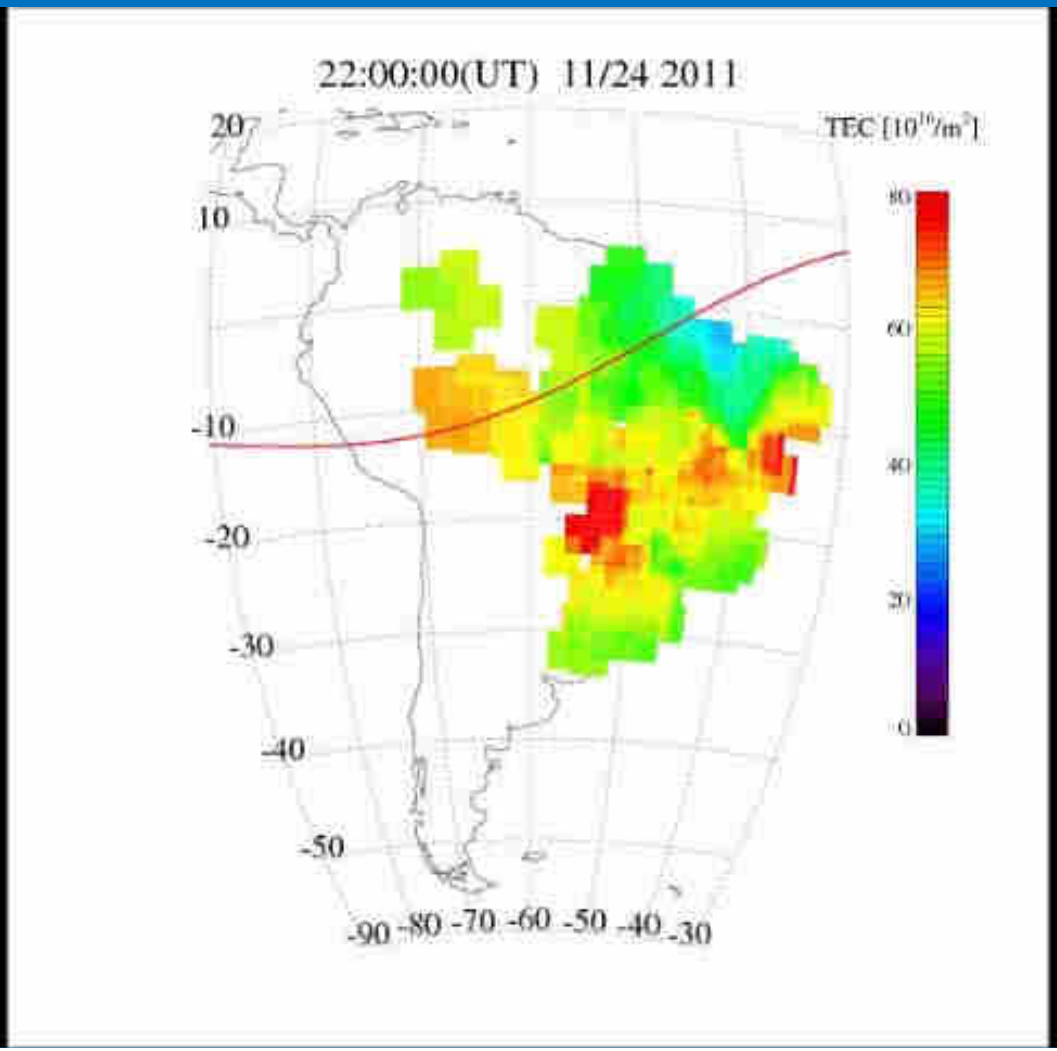


Plasma Bubble Activities observed by GPSTEC

TECMAP: 2011.11.24-25

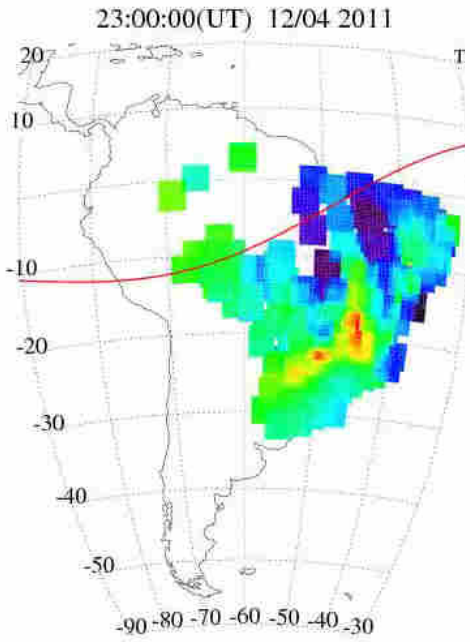
(19:00 – 03:00 LT)

video

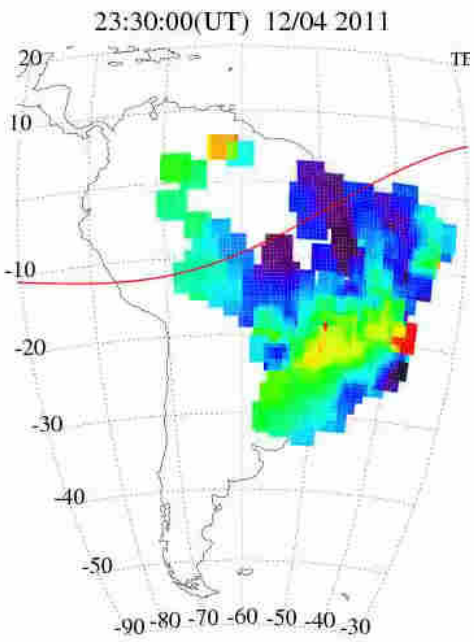


Latitudinal and longitudinal Plasma bubble structures observed in the evening of 2011.12.04, 23:00 – 24:00 UT

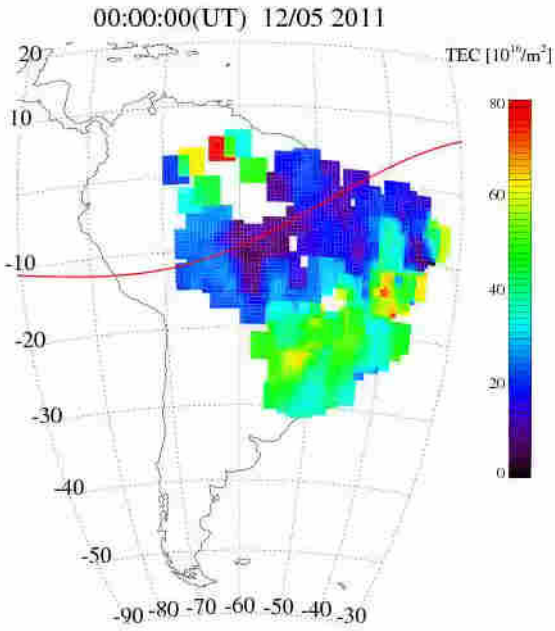
23:00 UT



23:30 UT



24:00 UT

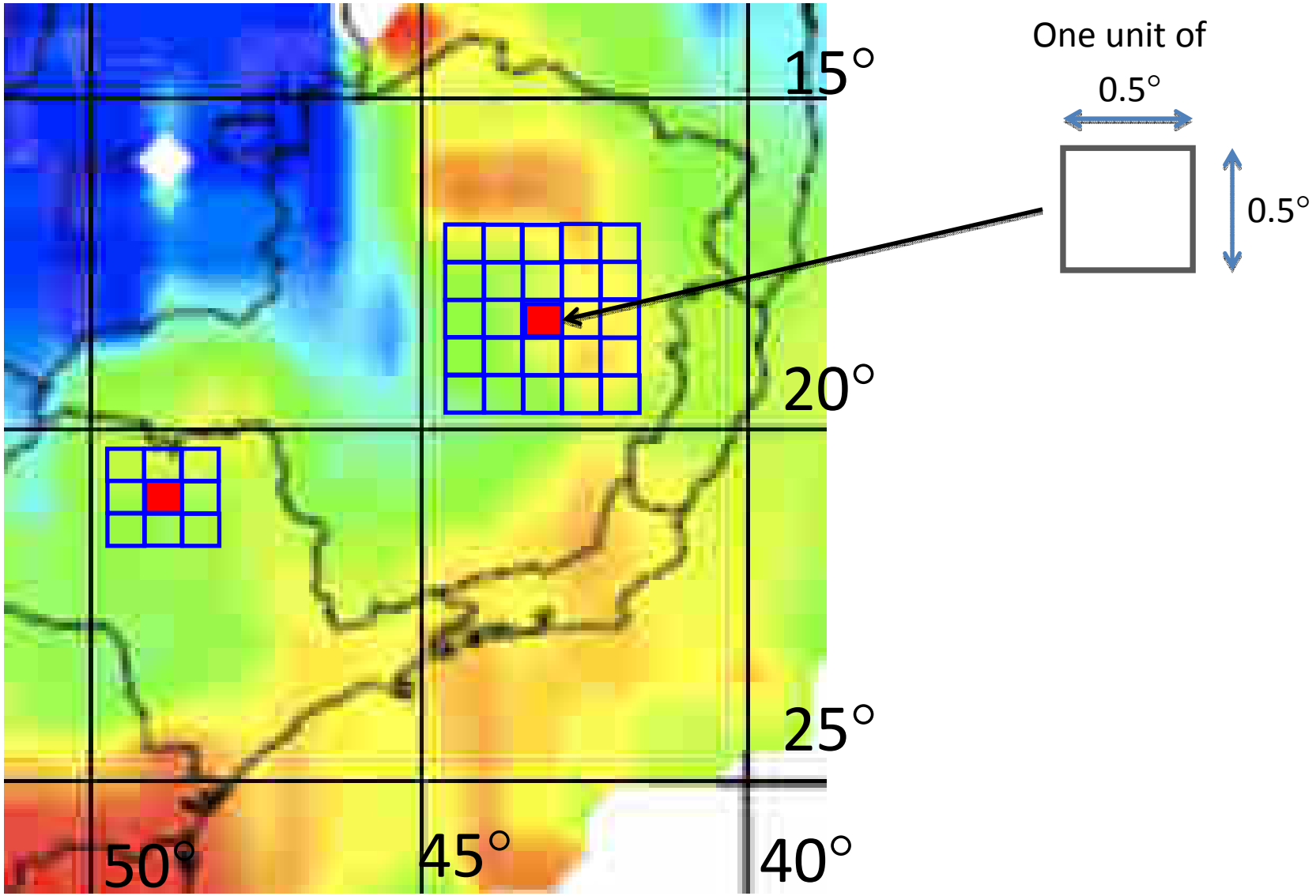


Latitudinal extension: at least 20 degrees in SH

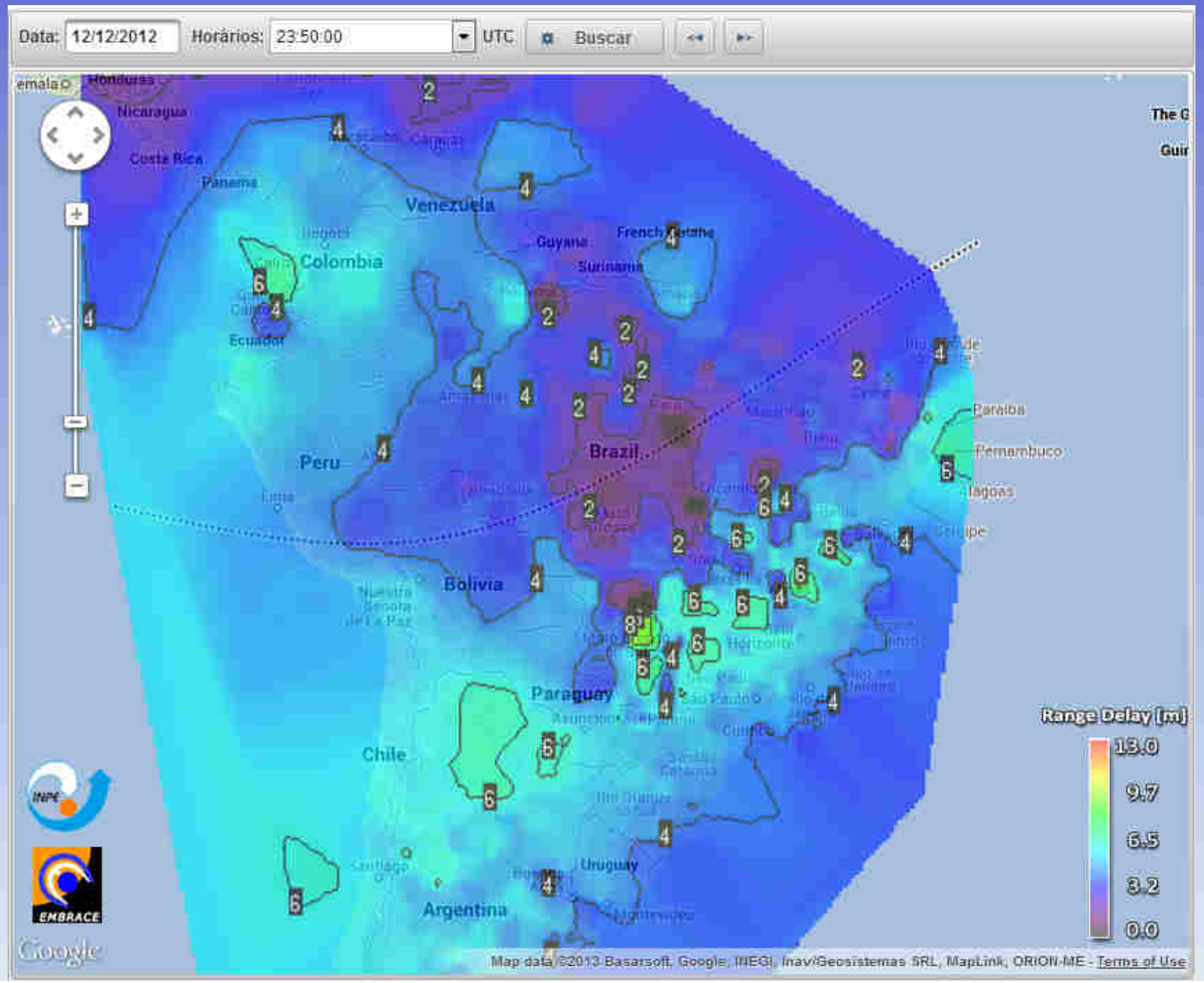
Longitudinal distance between the bubbles: ~ 1000 km,

Drifting Eastward by ~ 5-8 deg/hour (~200 m/sec)

Improvement of spatial resolution: moving average: 3x3, 5x5, 7x7 elements



Vertical Delay Map:
2012-12-12, 20:50 LT



Conclusions

- Temporal variations of the Equatorial Anomaly and Plasma Bubbles can be monitored in real-time,
- Estimation of “vertical delay” is in progress.

Workshop do Clima Espacial

2º Workshop do Centro de Informação e Previsão de Clima Espacial do INPE com Usuário,

11 de outubro de 2013, INPE, São José dos Campos, SP