

GPS Meteorology: Concepts and possibility of application in Brazil

Prof. Dr. João Francisco Galera Monico
Luiz Fernando Sapucci

Faculty of Science and Technology (FCT) - São Paulo State University (UNESP)
FCT/UNESP - Pres. Prudente, São Paulo, Brazil

Prof. Dr. Luiz Augusto Toledo Machado
Center for Weather Forecasts and Climate Studies
CPTEC/INPE - São Jose dos Campos – São Paulo – Brazil

Prof. Dr. Artemio Plana-Fattori
Atmospheric Sciences Department –
IAG-USP, São Paulo, SP, Brazil

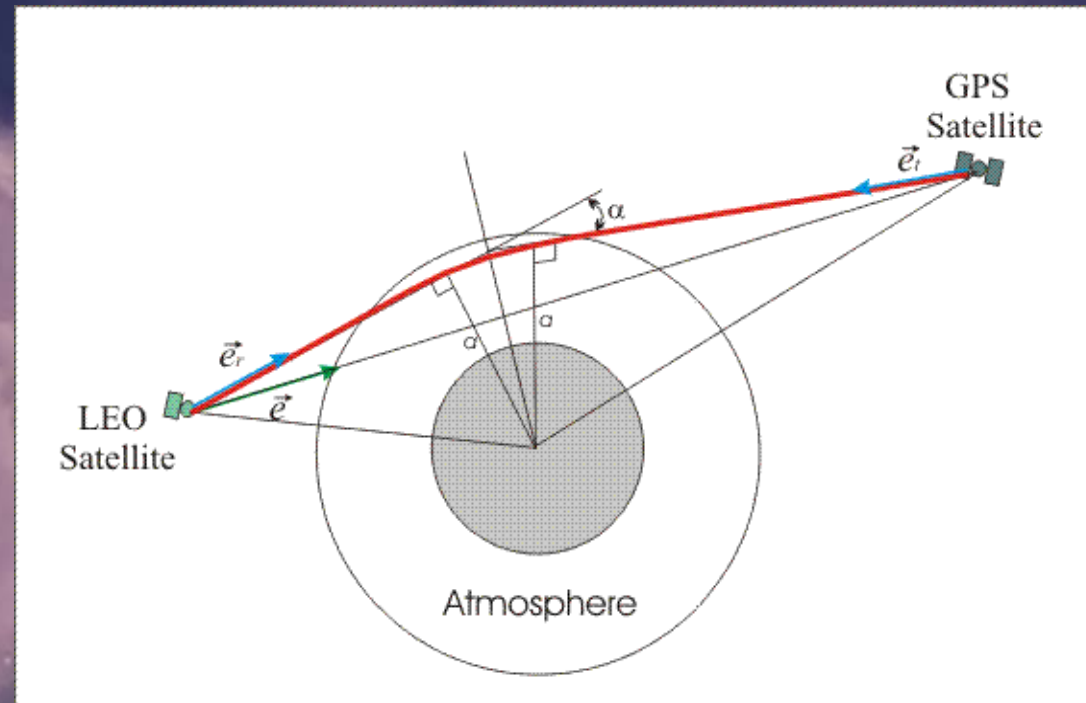
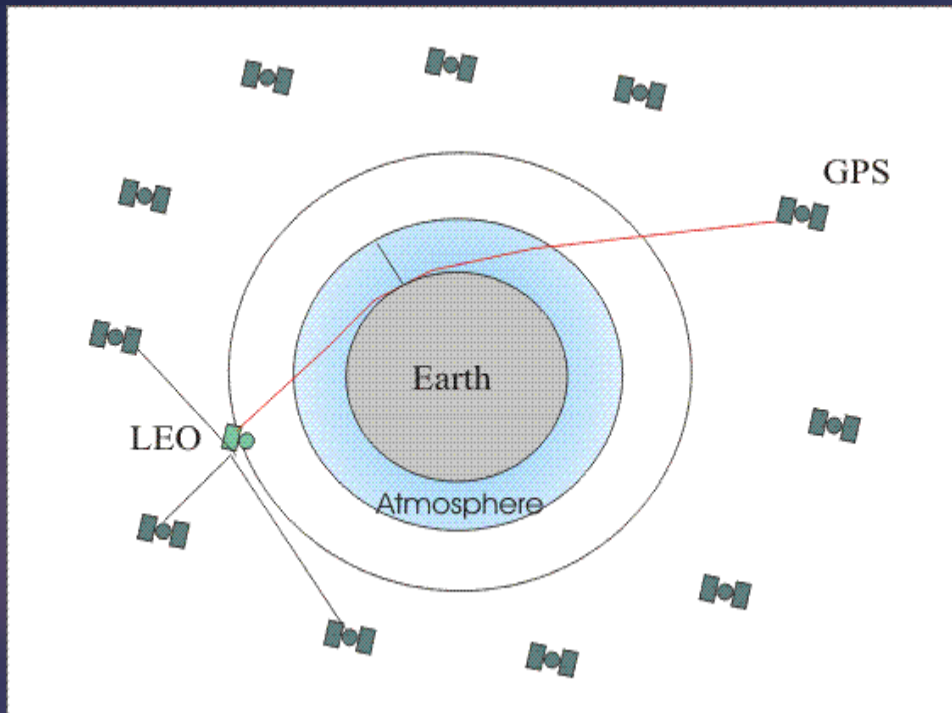
Introduction

- GPS Meteorology (GPS/Met) is a very new and challenge field of research and applications;
- Promoting the use of GNSS in Meteorology may be a field of interest of OOSA



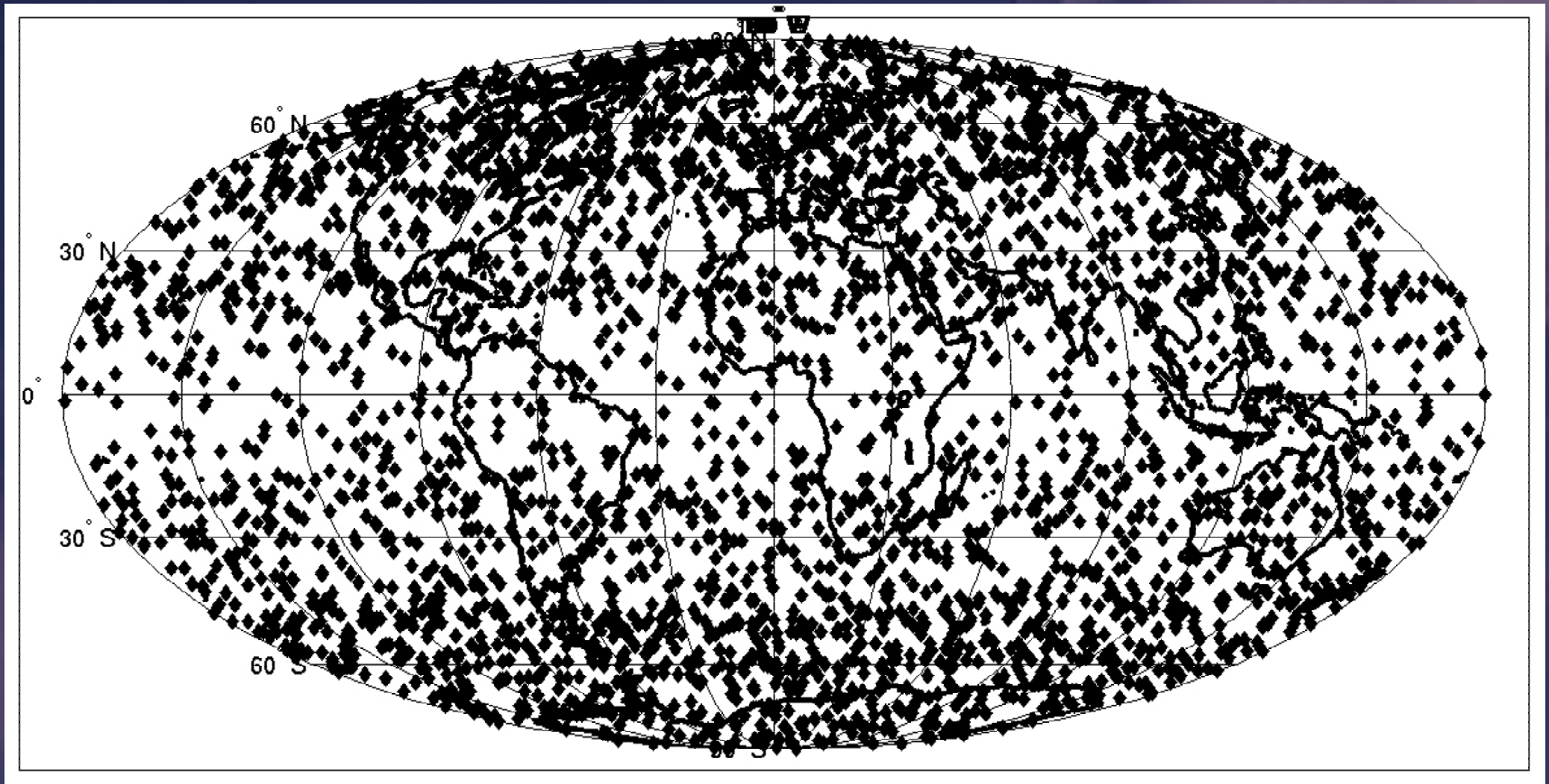
Introduction

- GPS Meteorology;
 - Space Based; (CHAMP, COSMIC, EQUARS, ...) GPS Occultation



CHAMP: Challenging Minisatellite Payload for Geophysical Research and Application
COSMIC- Constellation Observing System for Meteorology, Ionosphere & Climate
EQUARS – Equatorial Atmosphere Research Satellite

COSMIC GPS Occultation

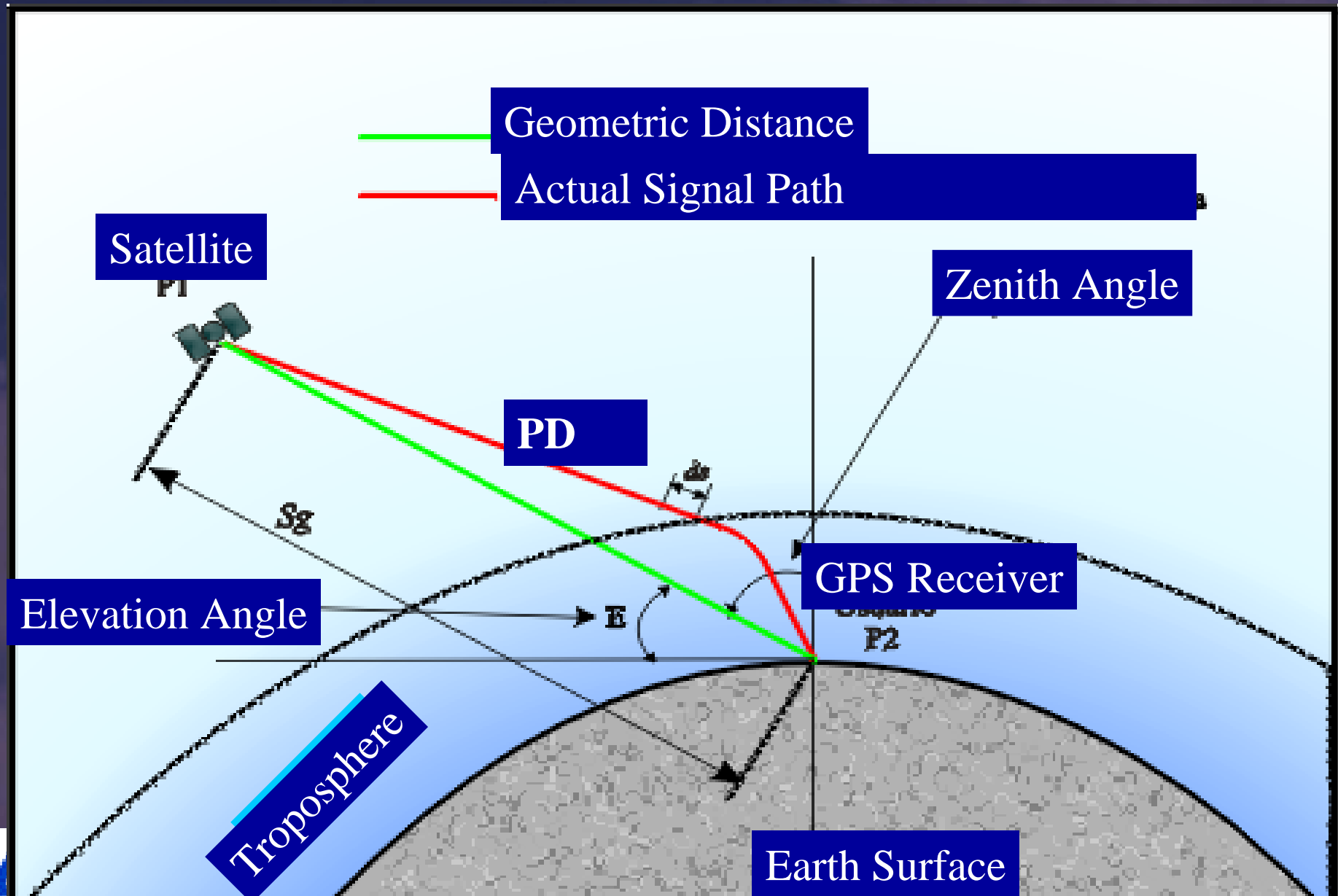


<<http://www.cosmic.ucar.edu/press.html>>.



- Ground Based:

- From GPS receiver on the ground, one can estimate the total tropospheric delay (D_{TROP});



- Ground Based:

$$D_{TROP} = D_{ZH} + D_{ZW}$$

- It is composed of two components: hydrostatic and wet delays ...

$$D_{ZH} = (2,27671422 \times 10^{-3}) \frac{P_0}{(1 - 0,0026 \cos 2 \varphi - 0,00028h)}$$

- Therefore:

$$D_{ZW} = D_{TROP} - D_{ZH}$$

- The accuracy is claimed to be of the order of 4-12 mm,



Objectives

- **To present the Concepts of GPS Meteorology – Ground Based;**
- **To introduce the present and future situation of GPS Meteorology in Brazil and the possibilities of applications and of a Pilot Project in this area.**



Basics of GPS/Met – Ground Based

- Once one obtain D_{ZW} it can be converted to IWV by applying the following equation:

$$IWV = D_{ZW} \Psi$$

$$\Psi = \frac{10^6}{R_w \left[k_2' + \frac{k_3}{Tm} \right]}$$

- $R_w = (461,5181) \text{ Jkg}^{-1}\text{K}^{-1}$ specific constant of WV
- $k_2' = 22,10 \text{ K hPa}^{-1}$ and $k_3 = 373900 \text{ K}^2 \text{ hPa}^{-1}$
- Tm is the mean weighted temperature of the atmosphere along the vertical coordinate.



How to obtain T_m ?

- T_m is frequently obtained from surface temperature (T_s), by applying a model that relates T_m and T_s ;
 - An global example is given by Schueler et al., (2002):

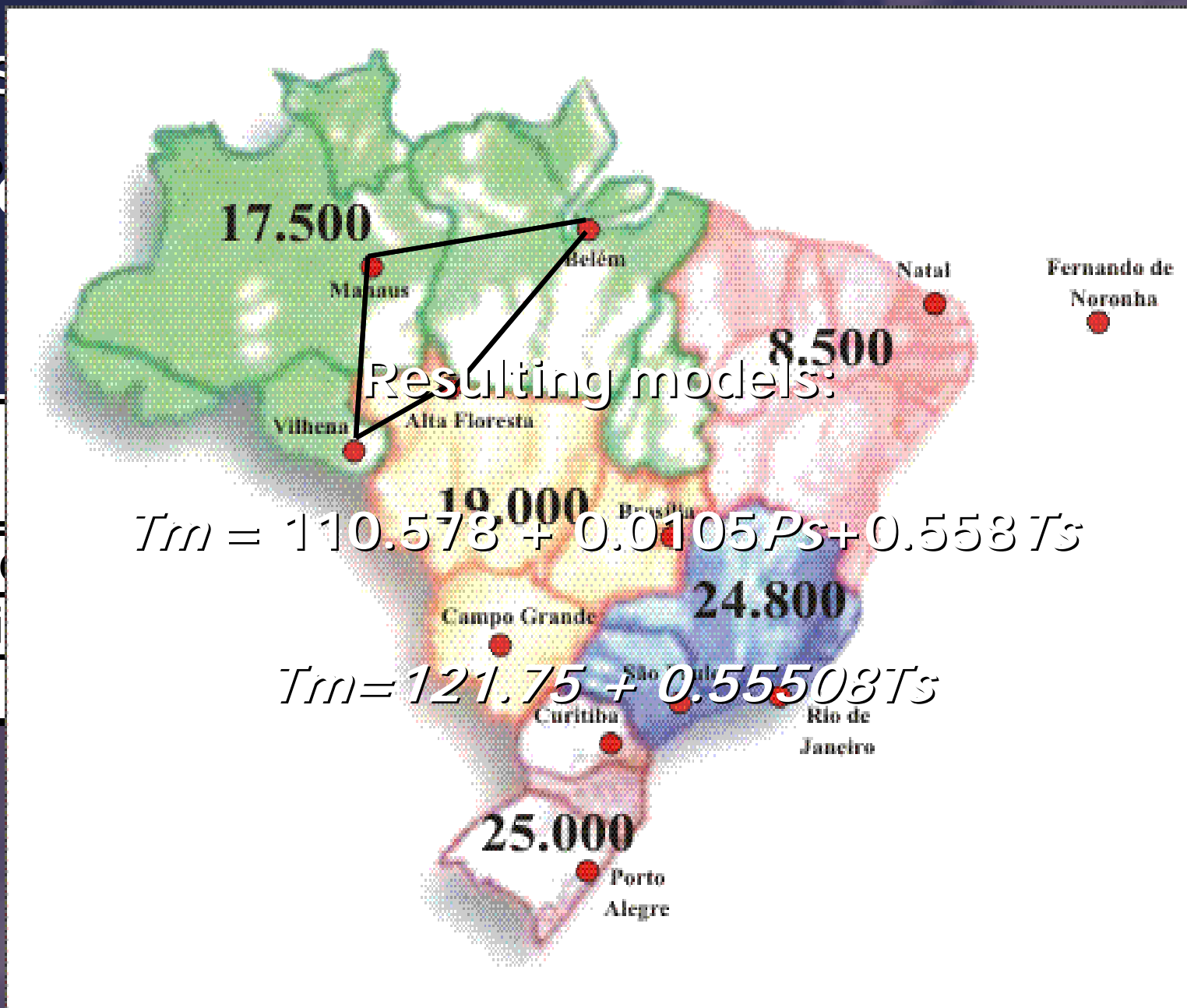
$$T_m \approx 86,9 + 0.647 T_s + \textit{corrections}$$

- Precision of about 2 to 5 K



A Tm model to be used in Brazil

- It was used for the design of radio systems in Brazil



historical
el

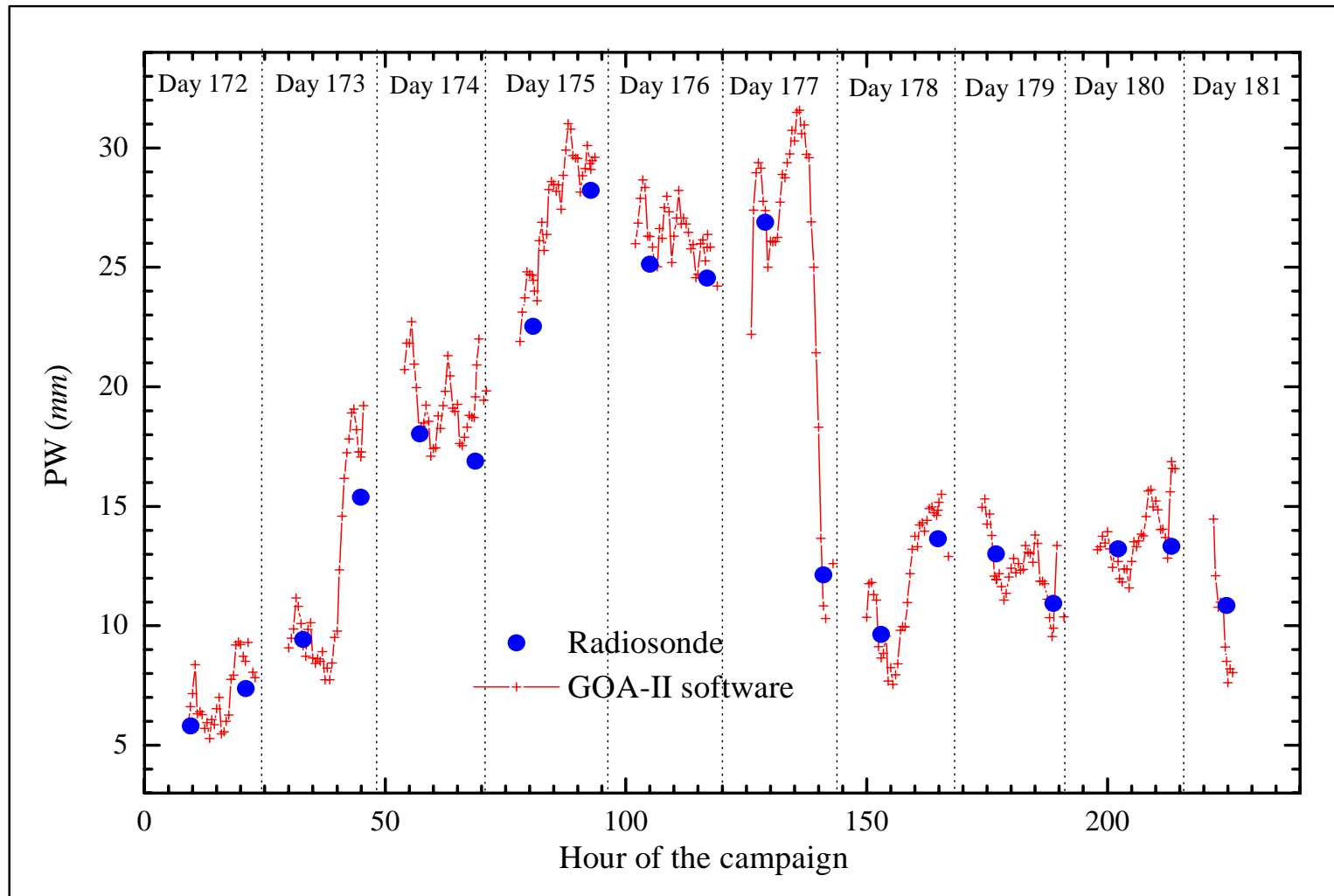
Site
Nossa Senhora
Guajara Mirim
Porto Velho

RMS (K)
2.81
2.01
2.08



The first successful GPS/Met Experiment in Brazil - 2001

Wet delay below 19 cm

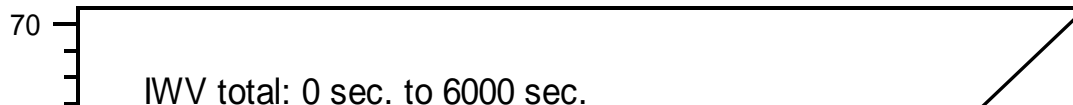


Ho

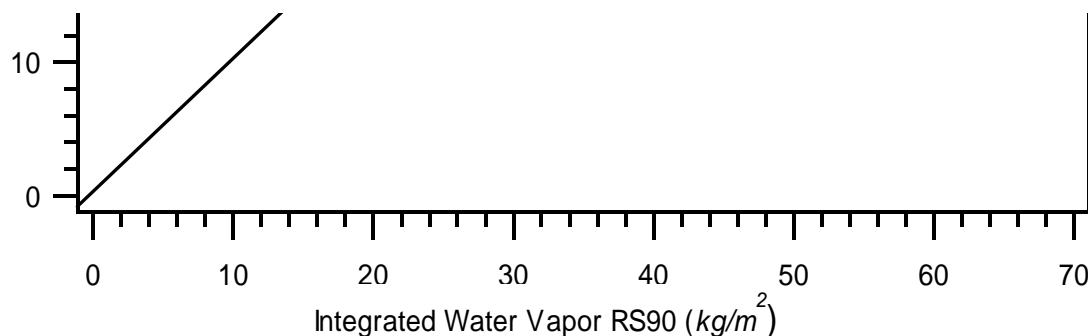
?



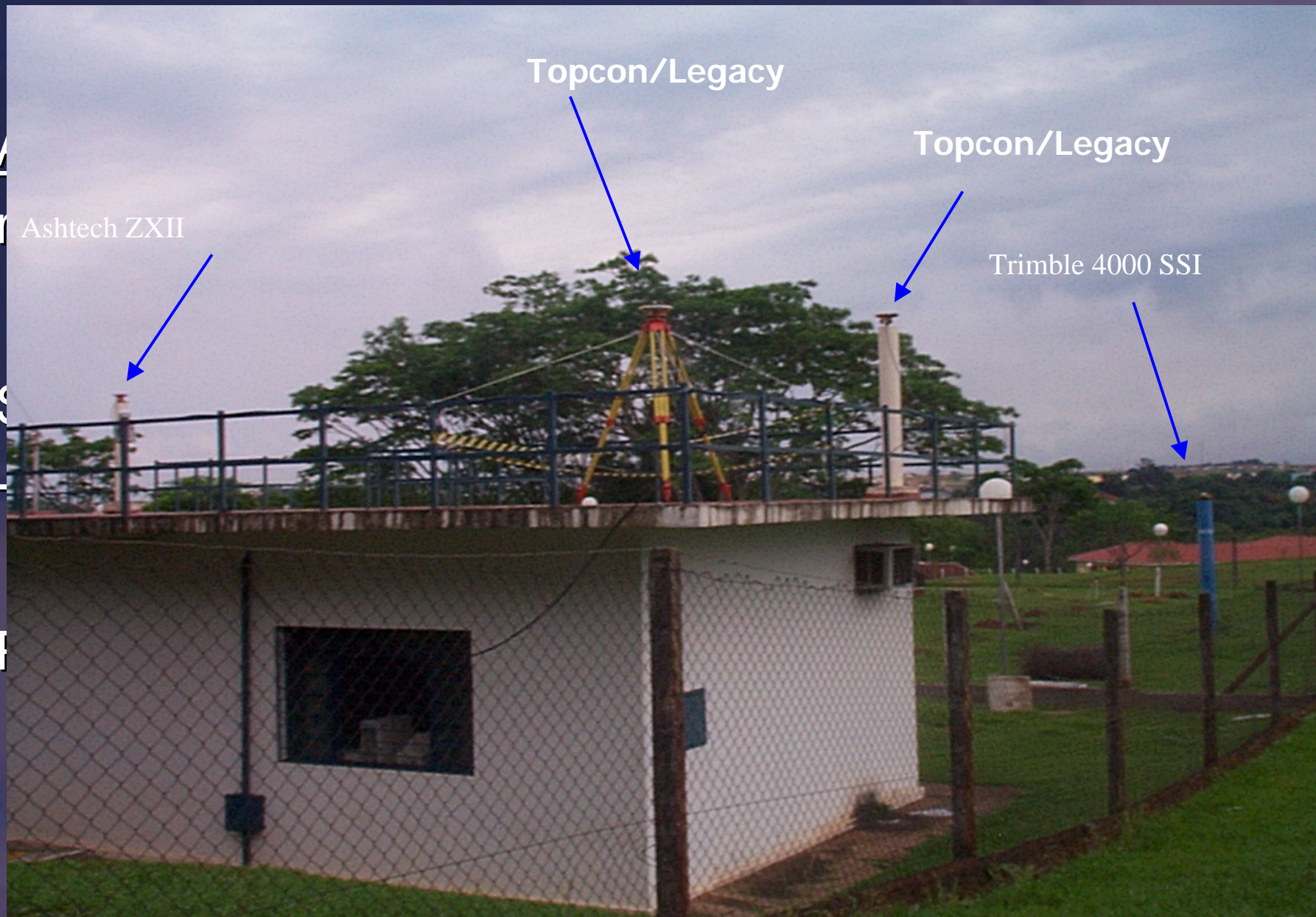
Radiosondes intercomparison Campaign



Comparison Rad-RS80	Flight Numbers	Layers (km)				(kg/m ²) Total Content
		0 a 3	3 a 8	8 a 15	15 a 30	
RS90	18	1.124	0.387	0.041	0.005	1.271
MKII	33	4.158	1.972	0.218	0.007	4.605
GL-98	20	1.696	0.542	0.073	0.006	2.202
DFM-97	16	2.198	0.547	0.029	0.112	2.565
SW	16	2.186	0.594	0.080	0.047	2.413



GPS intercomparison campaign



-
-
-

ent
at :



Results of the GPS Intercomparison



Compared Receivers	Estimate Numbers	D_{zwd} (mm)		IWV (kg/m^2)		
		BIAS	RMS	BIAS	RMS	RMS(%)
Trimble-ZXII	2676	-2.50	6.60	-0.39	1.04	2.5%
Legacy1-ZXII	3167	-7.80	9.10	-1.23	1.43	3.5%
Legacy2-ZXII	3199	-9.80	11.20	-1.54	1.76	4.3%
Legacy1-Trimble	3269	-5.20	6.90	-0.82	1.09	2.7%
Legacy2-Trimble	3302	-7.50	8.80	-1.18	1.39	3.4%
Legacy2-Legacy1	3794	-2.20	3.80	-0.35	0.60	1.5%



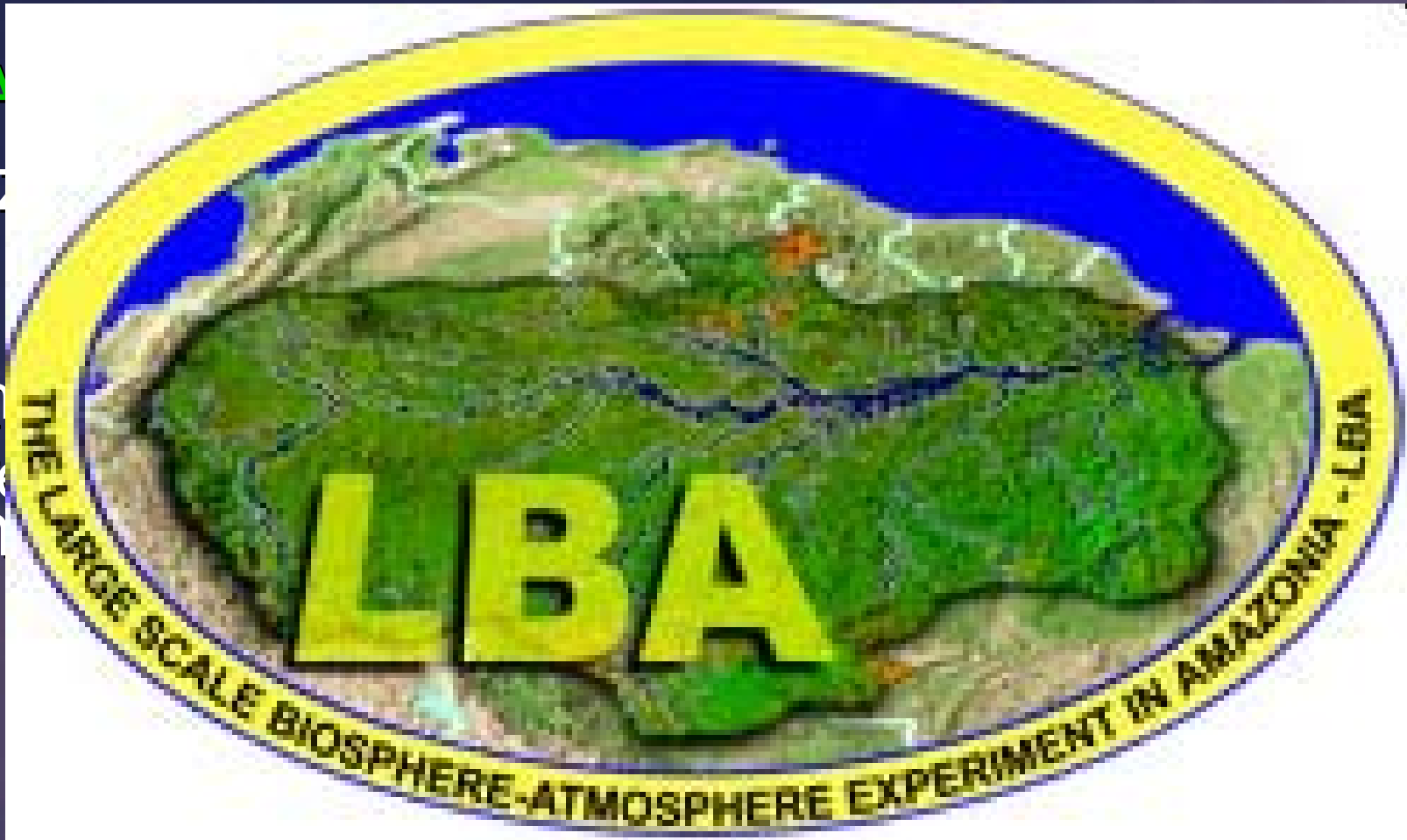
Accuracy of $(IWW_{GPS} - IWW_{RS})$?

$$\sqrt{1.1^2 + 1.2^2} \cong 1.6 \text{ kg} / \text{m}^2$$



GPS Campaign within the context of LBA

- LBA
Brazil
- In
– the
with
be
Am



ded by
help
actions
the

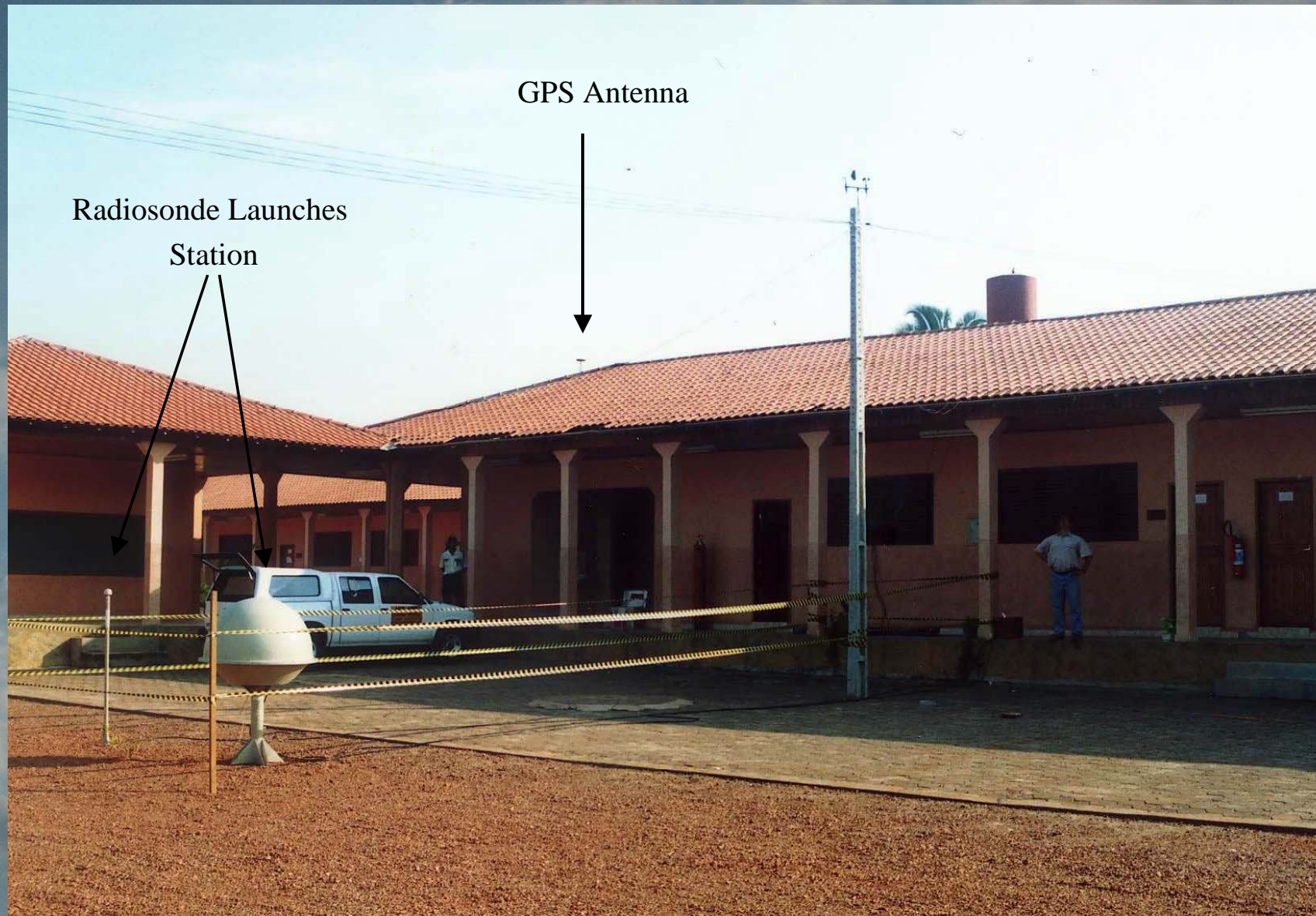


LBA Study areas and the GPS stations



- GPS Stations
- 6 radiosondes launches per day
- Other meteorological sensors
- Aeronet (Aerosol Robotic Network)
- Sun-sky radiometer (Brent Holben – NASA)



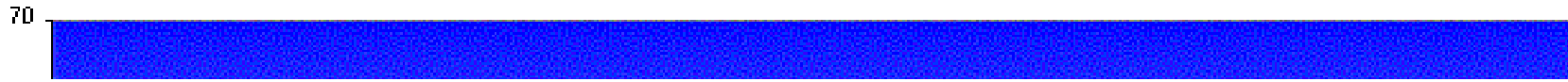


Radiosonde Launches
Station

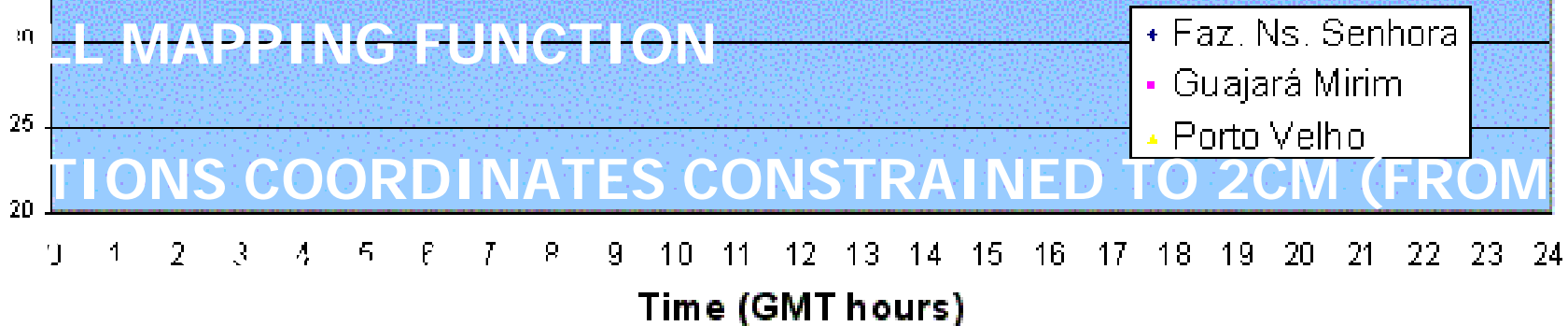
GPS Antenna

GPS data available and methodology

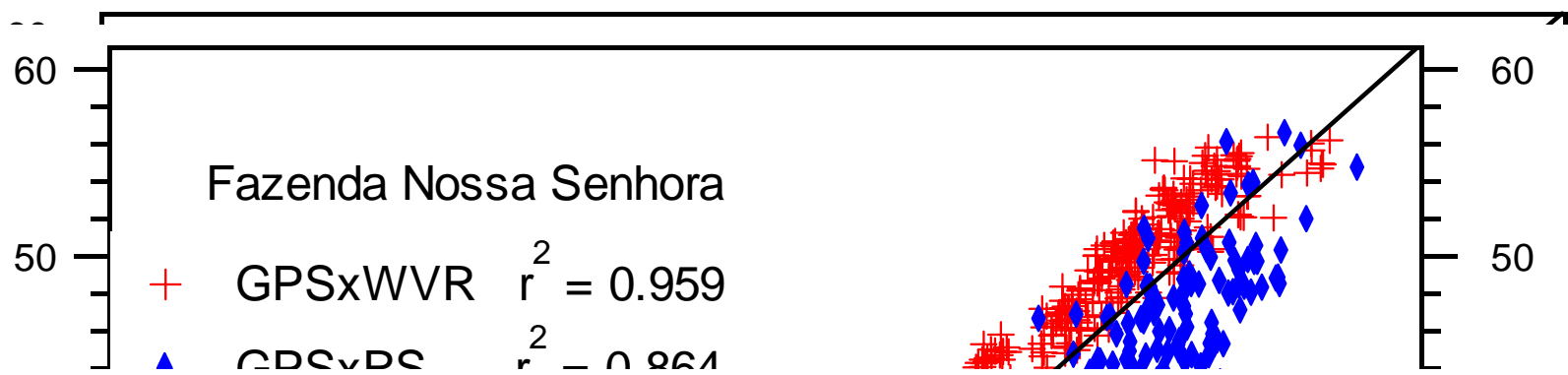
IONO values from RAOI GPS stations with temporal resolution of 5 minutes (September 27th, 2002)



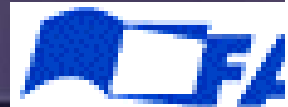
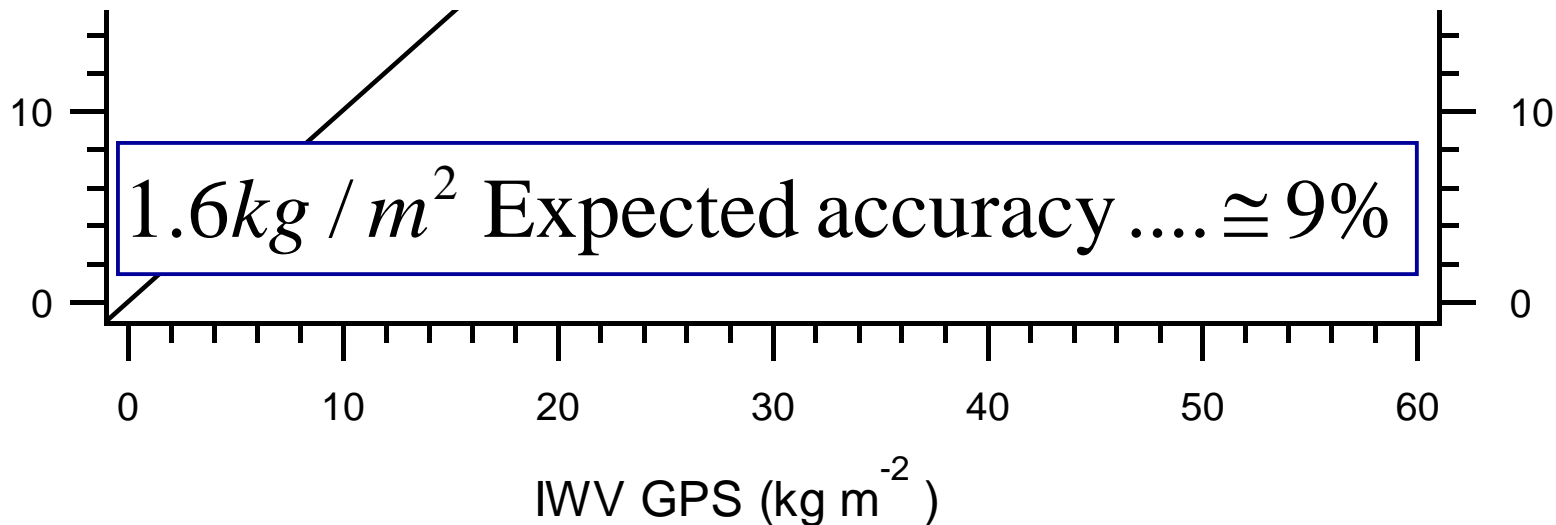
Site	September								October														Nov				
	15	17	19	21	23	25	27	29	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	1	3	
Ns. Senhora				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Guajará Mirim	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
Porto Velho			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		



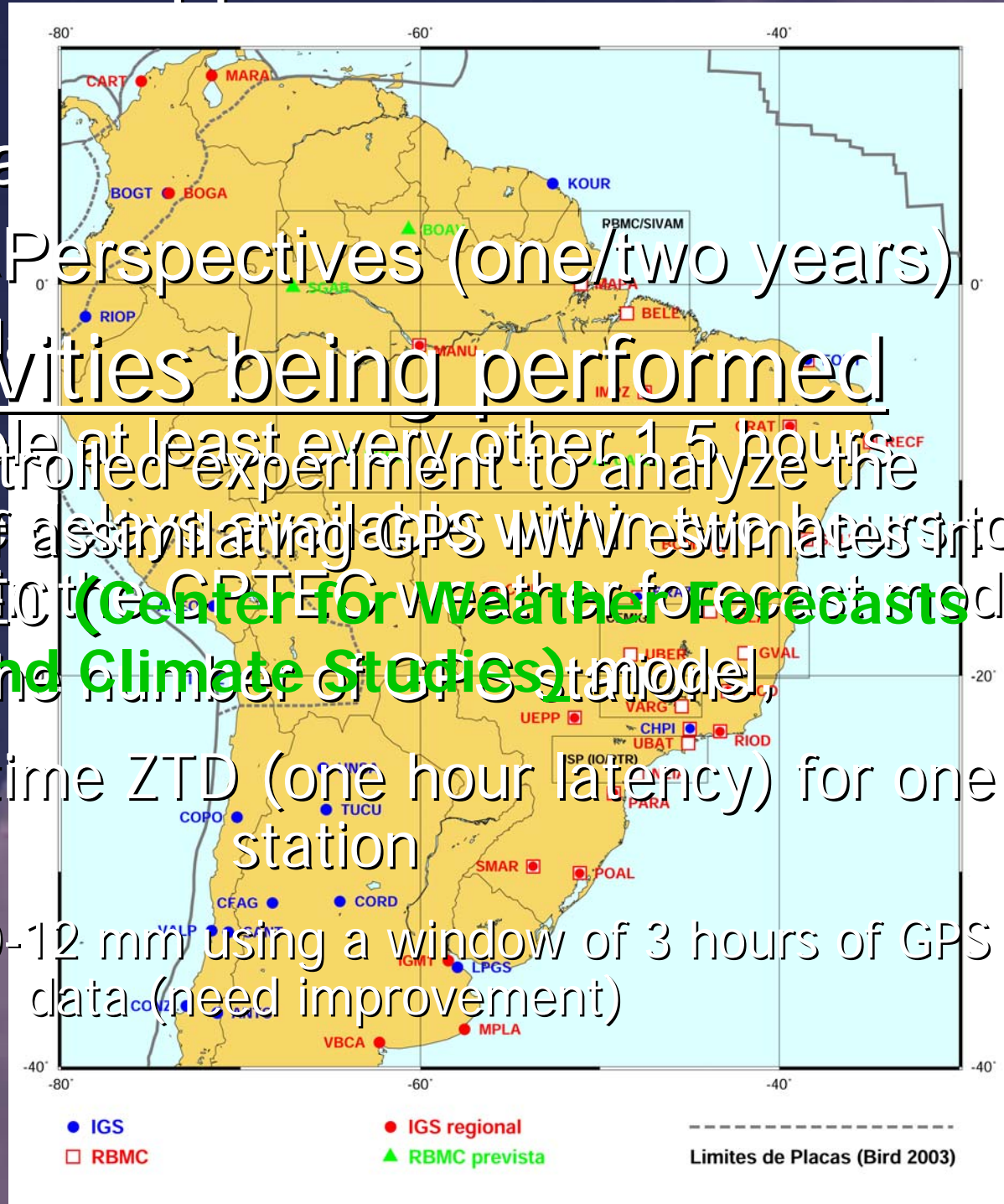
Preliminary Results



Compared Techniques	GPS Station	Comparison number	Bias (kg/m^2)	Standard deviation (kg/m^2)	RMS (kg/m^2)	RMS (%)
GPS – WVR	ABRA	304	-2.151	1.664	2.719	5.44
GPS – RS	ABRA	133	2.511	2.517	3.555	7.11
GPS – RS	GJMI	105	2.327	2.281	3.258	6.52
GPS – RS	PTVE	96	0.965	2.212	2.414	4.82



Perspectives of Applications of GPS/Met in Brazil



- Brazilia
 - Short period Data Perspectives (one/two years)
 - Available
 - Activities being performed
 - Data available at least every other 15 hours
 - A controlled experiment to analyze the impact of assimilating GPS WWV estimates into the assimilation (Center for Weather Forecasts and Climate Studies) model;
 - To expand the number of GPS stations
 - Near Real time ZTD (one hour latency) for one station
- Accuracy of 10-12 mm using a window of 3 hours of GPS data (need improvement)



:: Setor e Animação

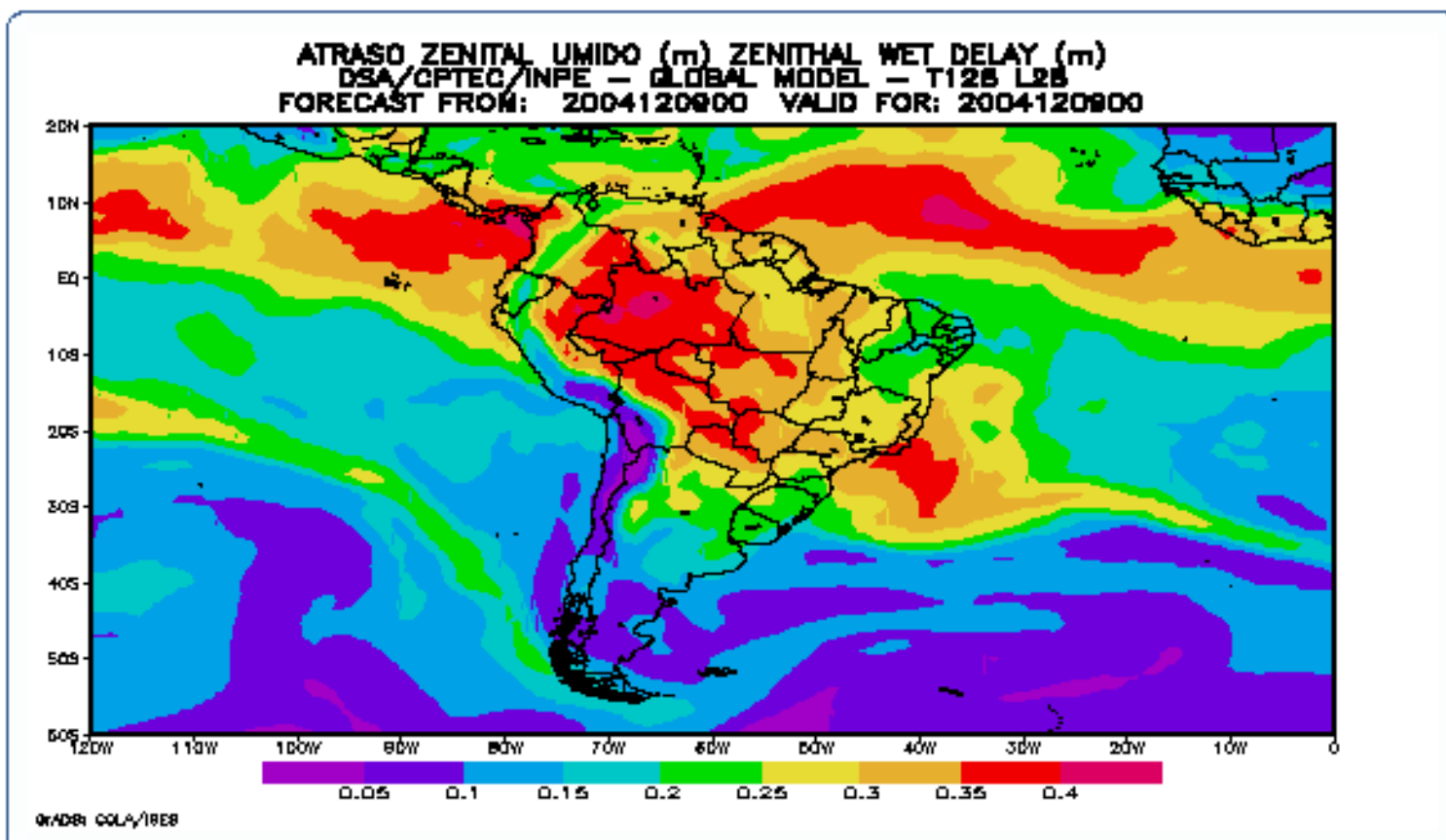
- [América do Sul](#)
- [Brasil](#)
- [Centro Oeste](#)
- [Nordeste](#)
- [Norte](#)
- [Sudeste](#)
- [Sul](#)

:: Notas

- [Atraso Zenital Troposférico](#)
- [Atraso Zenital Hidrostático](#)
- [Atraso Zenital Úmido](#)
- [Previsão do ZTD com Modelo de PNT](#)
- [Outras fontes e Ref. Bibliográficas](#)

[Indicadores de](#)

Previsões do Atraso Zenital Troposférico para sistemas de posicionamento por satélites (GPS ou GLONASS)



Comments and Conclusions

- The basic fundamentals of GPS Met was presented;
- A Tm model was developed for Brazil;
- Intercomparison of IWV was performed:
 - From radiosondes,
 - From GPS,
- IWV RMS absolute values from comparison of radiosondes and GPS are higher in the Amazonian region than the other tests performed;
 - but considering the high delays in that region, the percentage values are smaller (more research is needed),



Comments and Conclusions

- Perspectives of Applications of GPS/Met in Brazil was presented;
- Tests of assimilation of IWV are being performed using the CPTec numerical model –
 - It can be easily expanded to South America, since GPS IWV values are available;
 - It can be integrated within other projects, expanding the objectives....
 - And maybe, it can be a start point of a Pilot Project for South America in this field of GNSS application.

