



Instituto Nacional de Ciência e Tecnologia (INCT)

Tecnologia GNSS no Suporte à Navegação Aérea (GNSS-NavAer)



BRAZILIAN GNSS-NavAer INCT FOR SUPPORTING AIR NAVIGATION

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What is an INCT?

- INCT in Portuguese is the acronym for Instituto Nacional de Ciência e Tecnologia,
- One of the largest program of Science and Technology in Brazil.
- The aim of INCT: strategic areas for the sustainable development of the country
 - very ambitious,
 - embracing at the Brazilian level the possibilities of mobilizing and aggregating the best groups of research in the frontier of Science and Technology.

What is an INCT?

- competitive science and technology at international level,
- integrated with the industry for the benefits of the society.

- The last call was named INCT 16/2014.

- 12 main topics:
 - Controle e Gerenciamento de Tráfego Aéreo



LANÇAMENTO DA
CHAMADA PÚBLICA
INCT - 2014

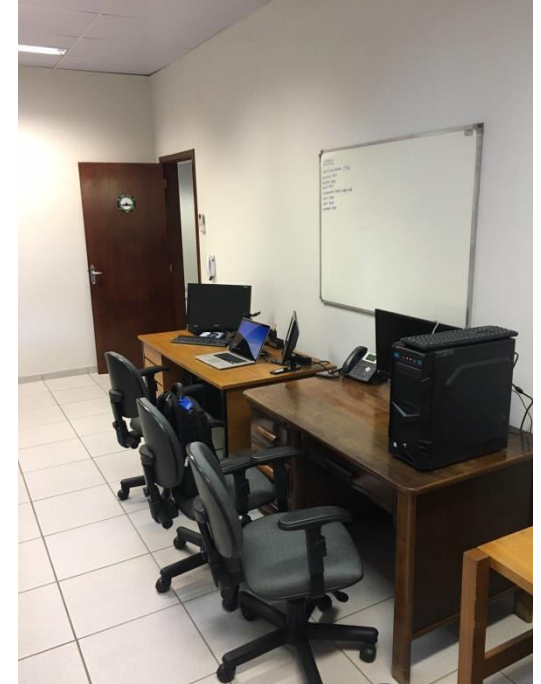


Ministério da
Ciência, Tecnologia
e Inovação



The GNSS-NavAer Project

- Researchers from UNESP, INPE, ITA and IAE:
 - submitted a 6 years project named “GNSS Technology to Support Air Navigation”,
 - **GNSS-NavAer**, which was approved.
 - Now also PUC-Rio, UFRGS and IFSP-Presidente Epitácio.
 - The second year of the project is running now.



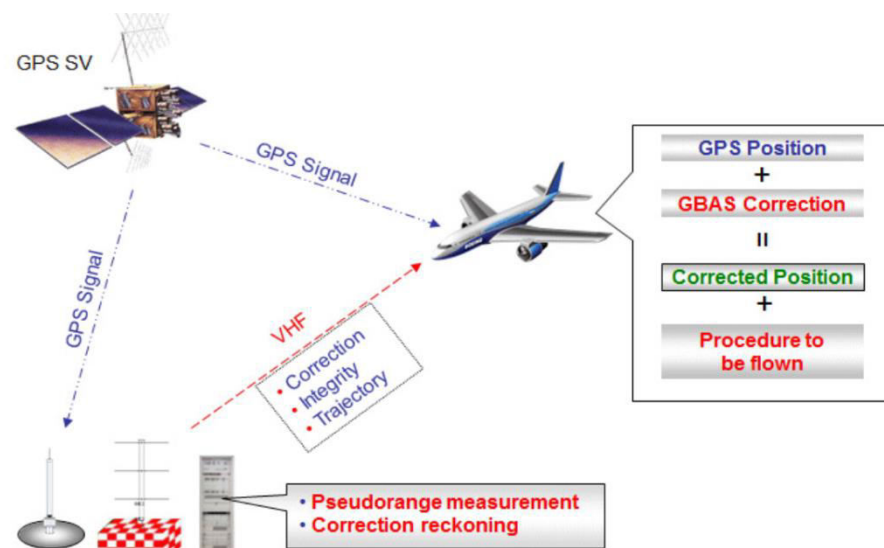
- The main stream of the project:
 - the problem of ionospheric irregularities, specially scintillation (IS) for air navigation at the Brazilian region when using GNSS.
- GNSS for aerial navigation:
 - a worldwide tendency in present days
 - in the future, the main technology for all flight phases.

The GNSS-NavAer Project

- GBAS (Ground-Based Augmentation System), which uses GNSS systems, transmitting corrections to improve the accuracy in determining the aircrafts position aiming at guiding it for a precise landing.

- Integrity is of the main concern:

- It involves accuracy, availability, and continuity at high level of probability (defined by ICAO).
- The Ionosphere in our region imposes several problems
 - Challenge for using in Safety of Life Applications



- Application of technologies based on GNSS in aviation over Brazilian territory demands a deep evaluation of ionospheric effects.

General Objective

To graduate human resources to develop researches and to transfer knowledge to the society, in the area of atmosphere monitoring, especially with the aspects related to the effects of TEC and IS in the GNSS signals,

To apply GNSS signals in the air navigation with reliability and safety in the Brazilian territory.

Specific Objectives:

- To research the ionospheric dynamics over the Brazilian territory, mainly the TEC and IS effects;
- Analysis of equatorial and low latitude ionosphere over the GBAS operation;
- Ionospheric threat model development suitable for the GBAS operation in the Brazilian airspace;
- Development of new GNSS positioning techniques for air navigation using the new GNSS signals;

...

...

- Improvement of the GNSS receivers performances under IS in the Equatorial Ionization Anomaly region;
- To provide the knowledge transfer to the Public & Private sector; and
- To promote the knowledge dissemination for the general public about the use of GNSS in the daily activities of the society.

- Ampliação da rede de receptores GNSS e sua manutenção;
- Definição/realização da estrutura de TI e transmissão dos dados;
- Formação de Mestres e Doutores e Especialistas para dar suporte às demandas da navegação aérea;
- Pesquisar a dinâmica da ionosfera (TEC e CI) sobre o território brasileiro;
- Análise dos efeitos da ionosfera equatorial e de baixas latitudes na operação do GBAS;
- Modelagem Estatística da CI;
- Desenvolvimento de um modelo de risco ionosférico para operação do GBAS no espaço aéreo brasileiro;
- Desenvolvimento de novas técnicas de posicionamento por GNSS na navegação aérea usando os novos sinais;
- Melhorar o desempenho dos receptores GNSS em ambiente com CI na região da Anomalia da Ionização Equatorial; e
- Prover a transferência de conhecimento e difusão do conhecimento .

What Have We Done So Far?

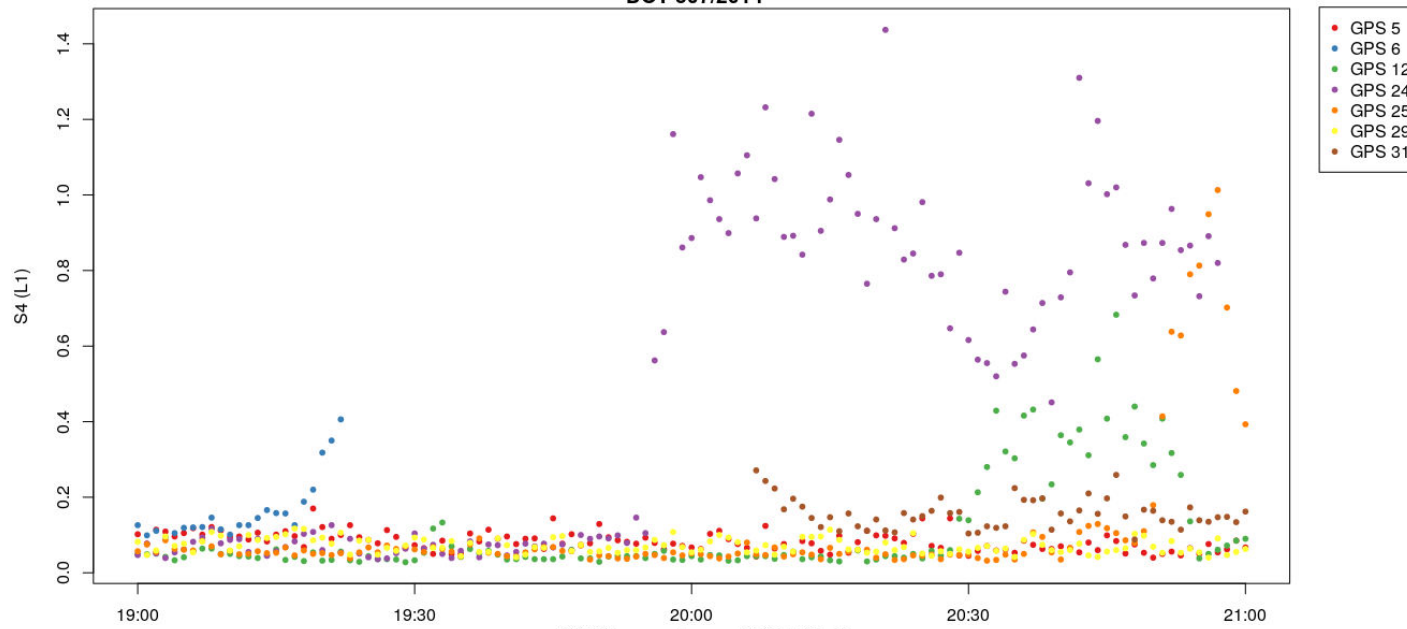
- **Mitigation of IS in the PPP;**
- **GBAS threat model analysis for Brazil;**
- **Observed and prediction IS maps**
- **Participação 14ª SNCT**
- **GNSS Networks integration at S4 level;**
- **Analysis of GNSS signal fadings;**

Mitigation of Scintillation Effects on Precise Point Positioning

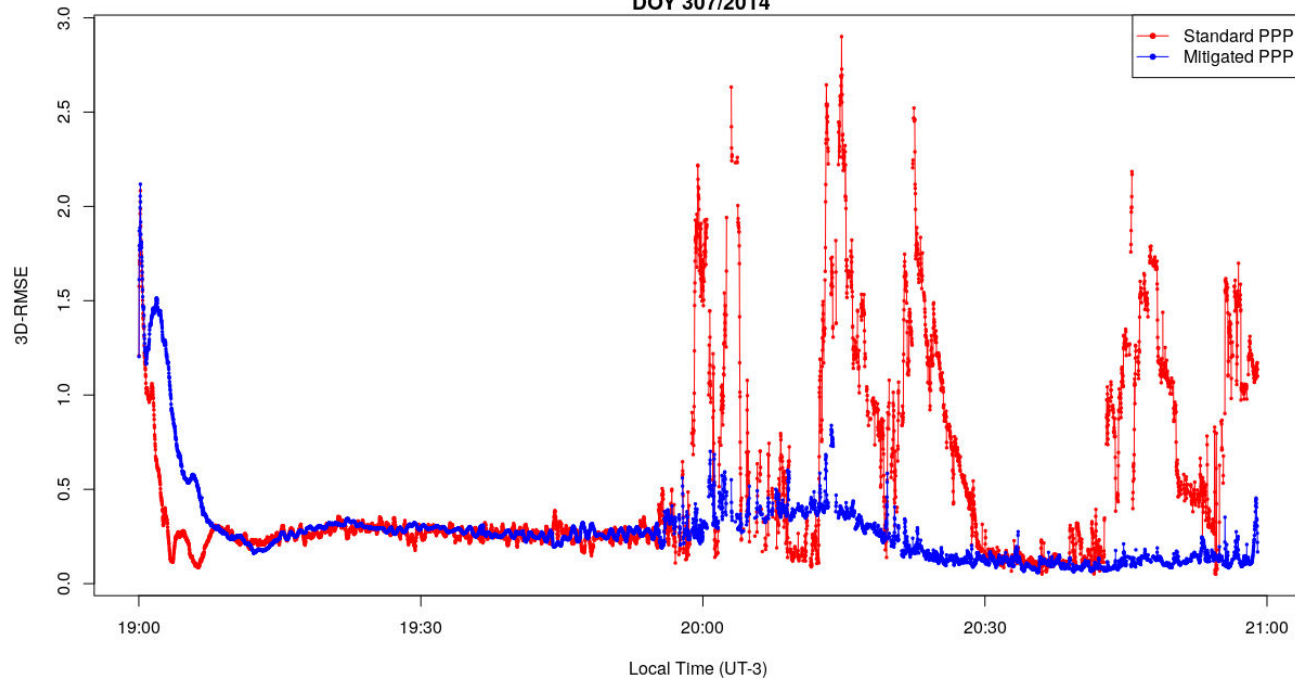
- PPP and RTK during strong scintillation can be deteriorated (if not properly modeled);
- Losses of lock, cycle slips and range degradation, lead to decreases in the positioning accuracy;

- Research on mitigation aims:
 - to model the scintillation effects and recover the accuracy to its expected level;

Scintillation - SJCUC Station
DOY 307/2014



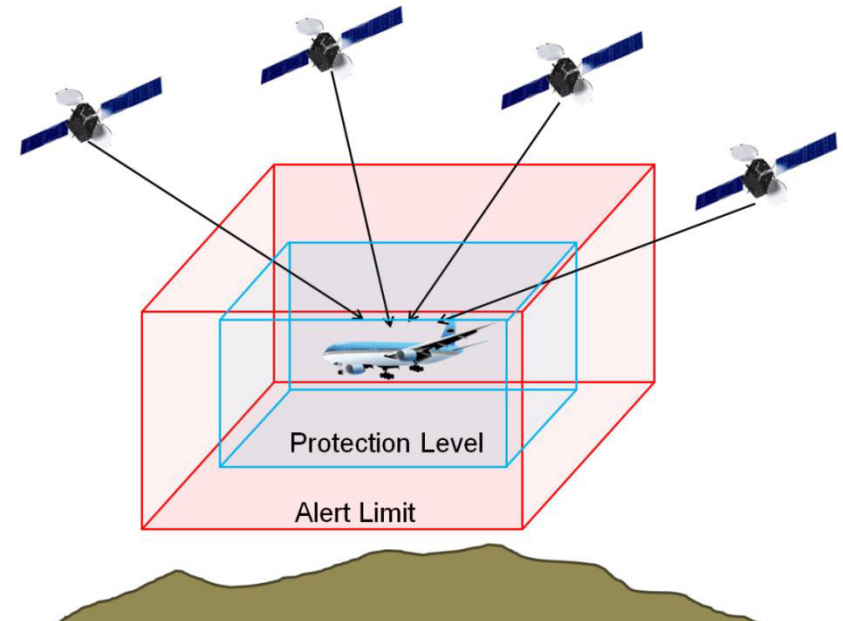
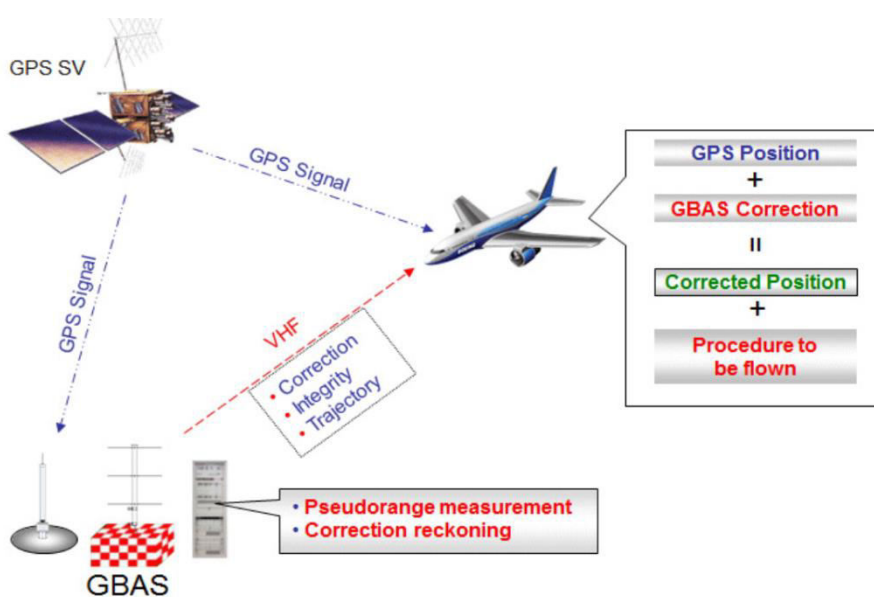
PPP Comparison - SJCUC Station
DOY 307/2014



- Mitigation applied to PPP
 - improvement of up to 80% in the positioning accuracy during strong scintillation

GBAS Threat Model

- Pereira (2018) computed a great number of ionospheric gradients for all available GNSS stations in Brazil since 2000, and estimated the integrity parameter σ_{vig} (vertical ionospheric gradient) in real-time for selected brazilian airports.
- It provides way to evaluate model for GBAS in Brazil.

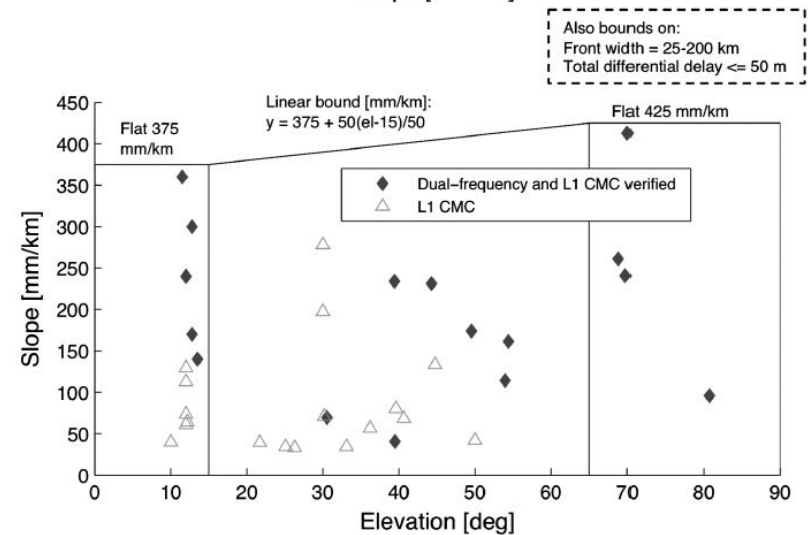
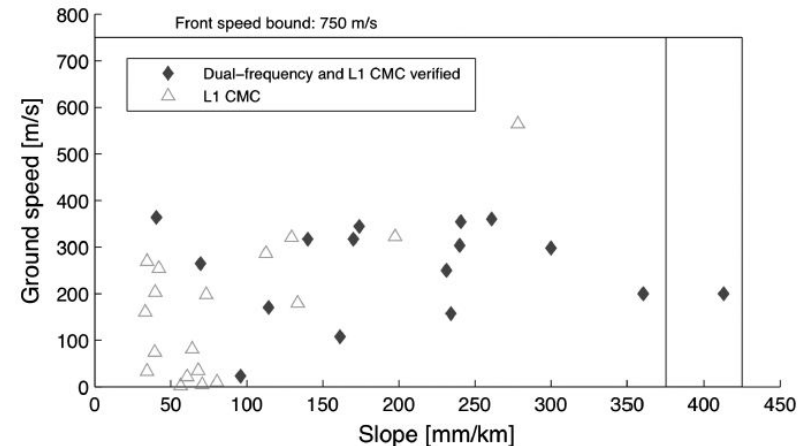


GBAS

- GBAS was developed for using in precision approaches (CAT-I, CAT-II, and CAT-III);
 - A category III C approach is a precision approach and landing with no decision height and no runway visual range limitation.
- Messages Type 1: differential corrections in GPS L1 pseudorange;
- Messages Type 2: integrity parameters of ionosphere, troposphere, multipath, airplane, ground station → estimate $VPL/HPL < VAL/HAL$ (ICAO);
- Messages Type 4: precision approach trajectories.

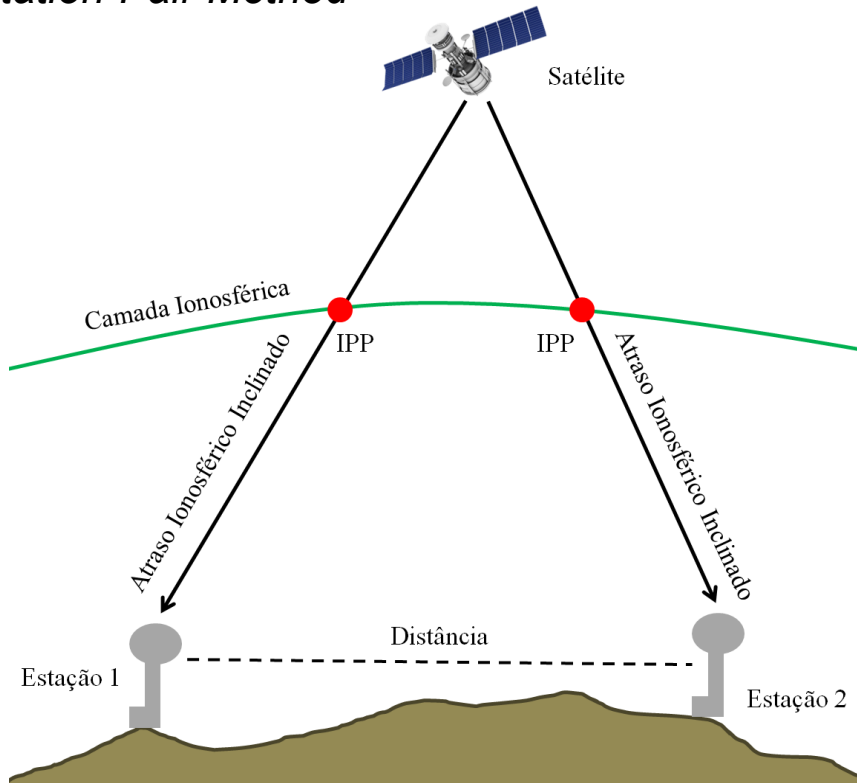
GBAS SLS-4000 da Honeywell

- The CONUS (CONTinuous United States) Threat Model for GBAS expects ionospheric gradient of the order of 425 mm/km, for the worst case.
 - In Brazil it can reach almost 1200 mm/km.



Gradient determination methods

Station-Pair Method

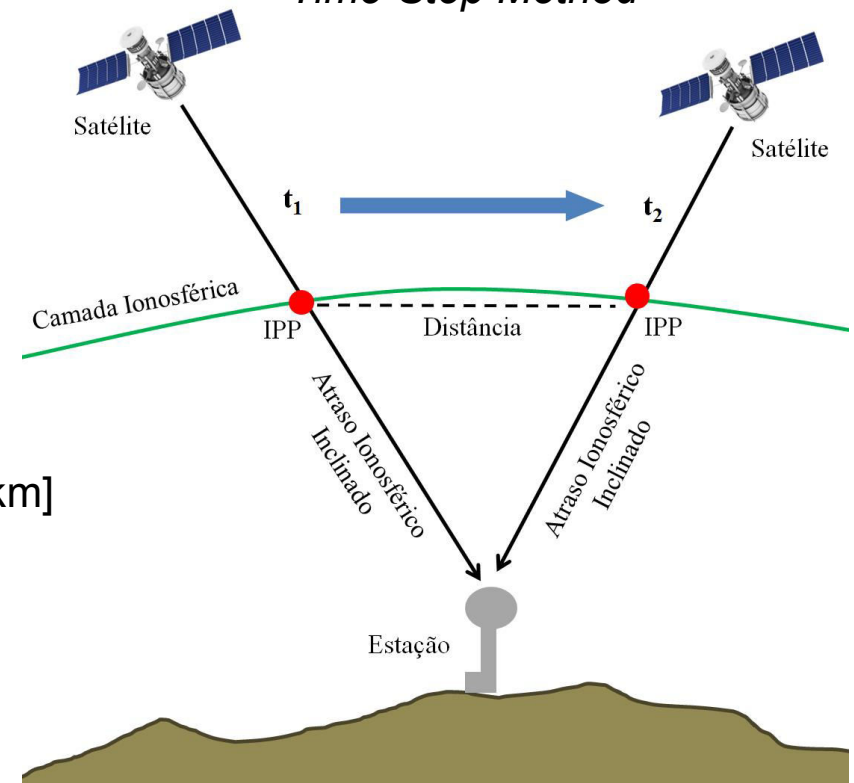


$$\sigma_{\sigma}^s = \frac{|I_{r1}^s - I_{r2}^s|}{D_{r1r2}}$$

$$I_r^s = \frac{\Phi_{rL1}^s - \Phi_{rL2}^s}{\gamma - 1} - \frac{c}{\gamma - 1} (\text{DCB}_r + \text{DCB}^s) - \frac{N_{rL1}^s - N_{rL2}^s}{\gamma - 1}$$

$$\sigma_{\sigma}^s = \frac{|I_{r t_1}^s - I_{r t_2}^s|}{D_{\text{IPP } t_1 t_2}}$$

Time-Step Method



[mm/km]

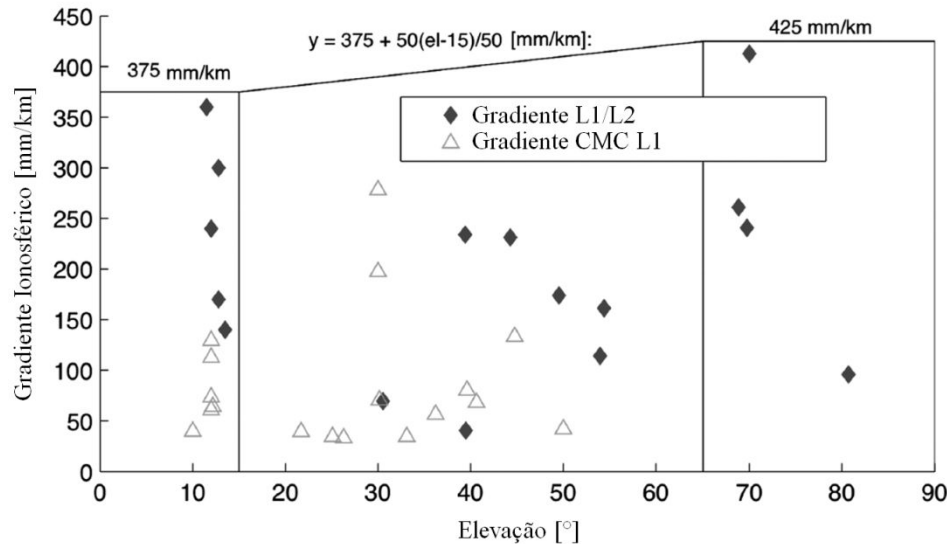
- Cada par de estações: uma estação GBAS e uma aeronave.
- Influenciado pelo DCB dos receptores.
- Ideal: LB em torno de 40 a 100 km e pares orientados paralelamente ao equador magnético.

- Aumento da amostragem de gradientes.
- Gradientes com distâncias menores (≈ 10 km).
- Arquitetura não intuitiva.
- DCB do satélite e receptor eliminado... Entretanto, tem-se a decorrelação temporal.

Investigations on Ion Threat Model

CONUS Threat Model

- Rede CORS.
- 10 dias – 2000 a 2004.

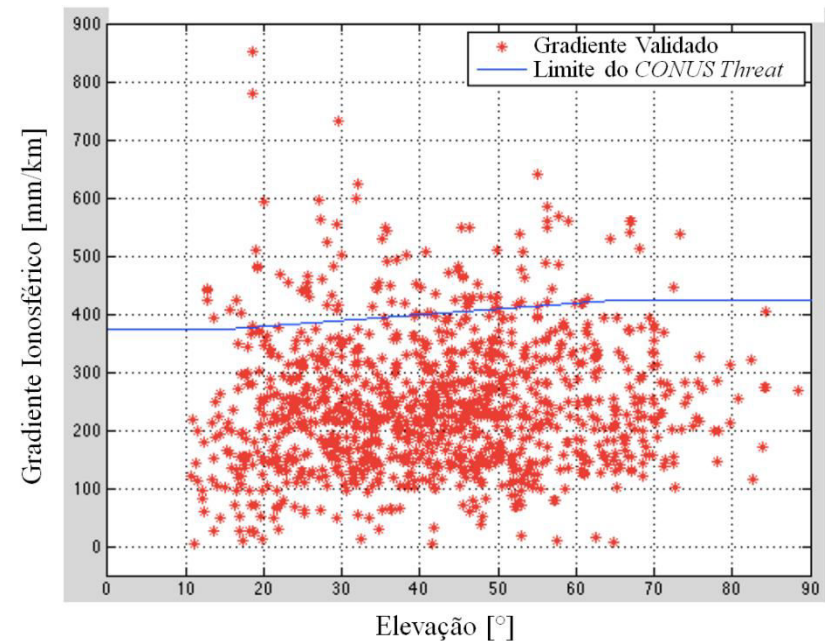


Fonte: Datta-Barua et al. (2010).

Parâmetro	Limite ou Variação do Parâmetro	
Gradiente Ionosférico Máximo	Elev. < 15°	375 mm/km
	15° < Elev. < 65°	$375 + 50 \cdot (Elev. - 15) / 50$ mm/km
	Elev. > 65°	425 mm/km
Velocidade da Frente Ionosférica	0 – 750 m/s	
Extensão da Frente Ionosférica	25 – 200 km	
Valor Máximo de Atraso Ionosférico	50 m	

Low Latitude Threat Model

- Mirus Technology/EUA, FAA, Stanford University, Boston College, INPE, ICEA e KAIST.
- RBMC, LISN, CIGALA/CALIBRA e ICEA.
- 120 dias – 2011 a 2014.

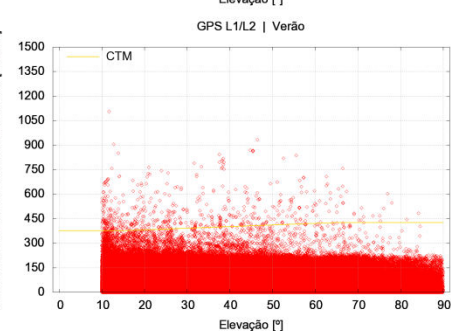
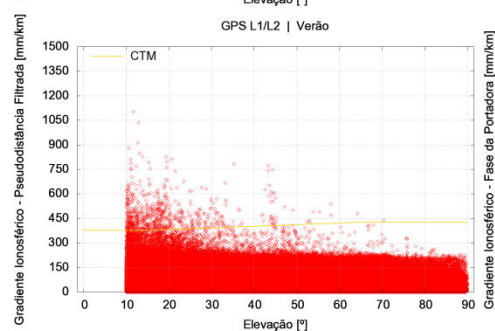
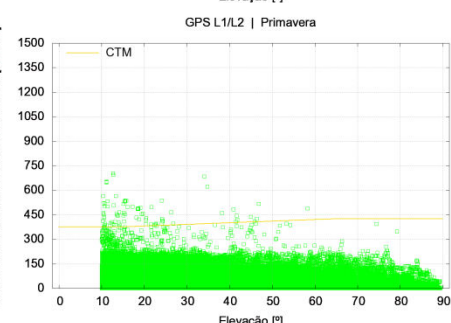
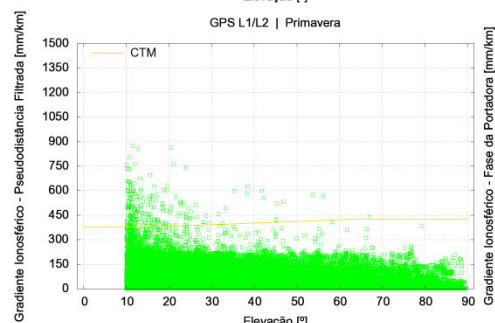
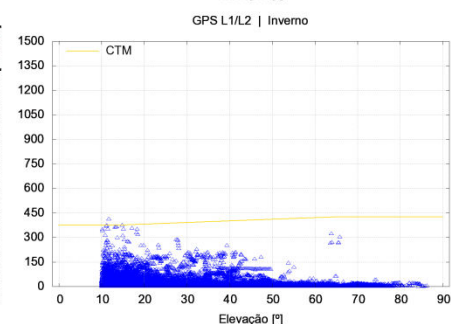
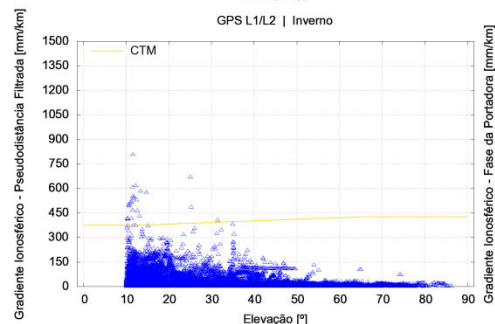
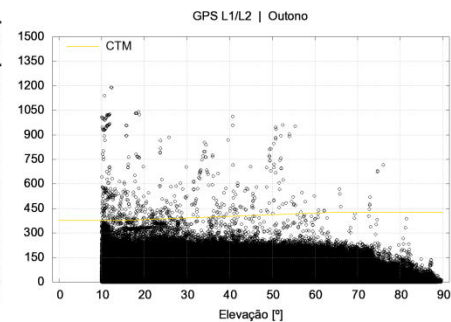
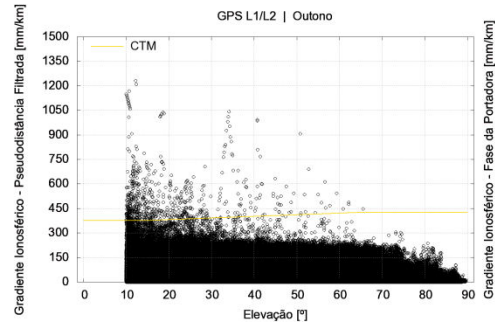


Fonte: Adaptado de USTDA (2015).

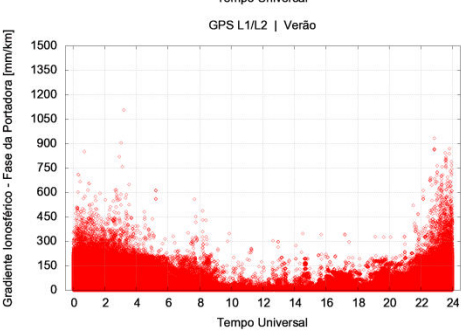
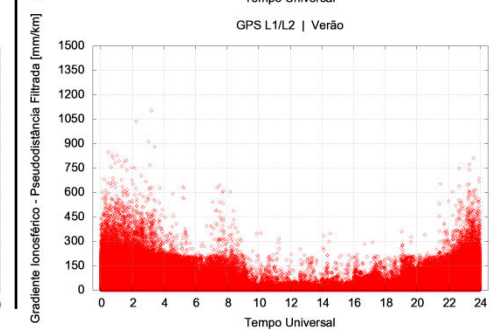
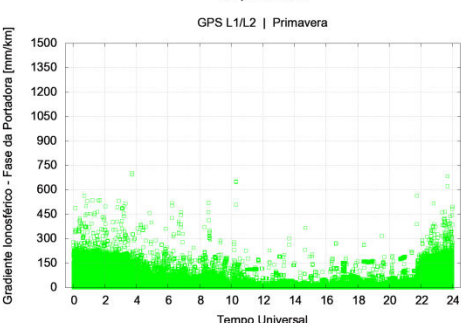
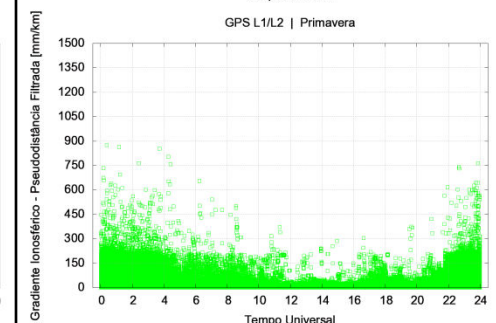
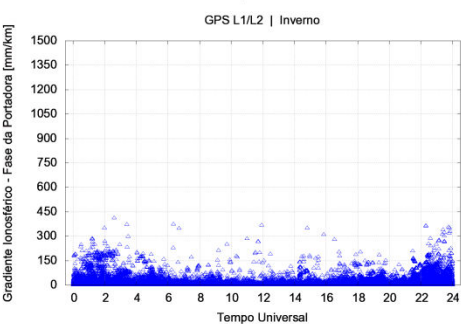
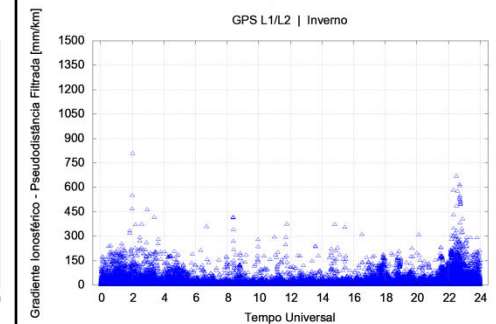
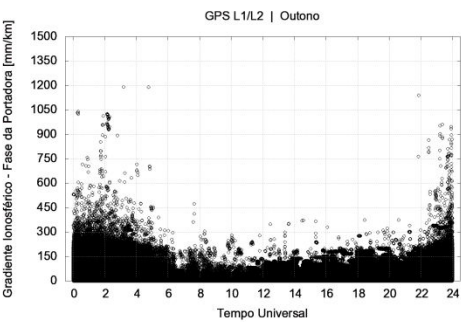
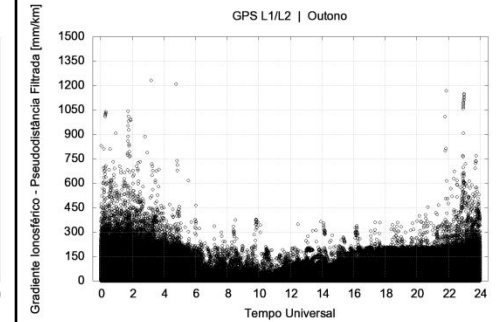
Ionospheric Parameters for GBAS Threat Models

- 307 days between the years 2000 and 2016;
- Data: GPS (L1/L2 and L1/L5), GLONASS (L1/L2) and Galileo (L1/L5); and
- Gradients from carrier phase and smoothed pseudorange to find the time windows feasible of using GBAS.

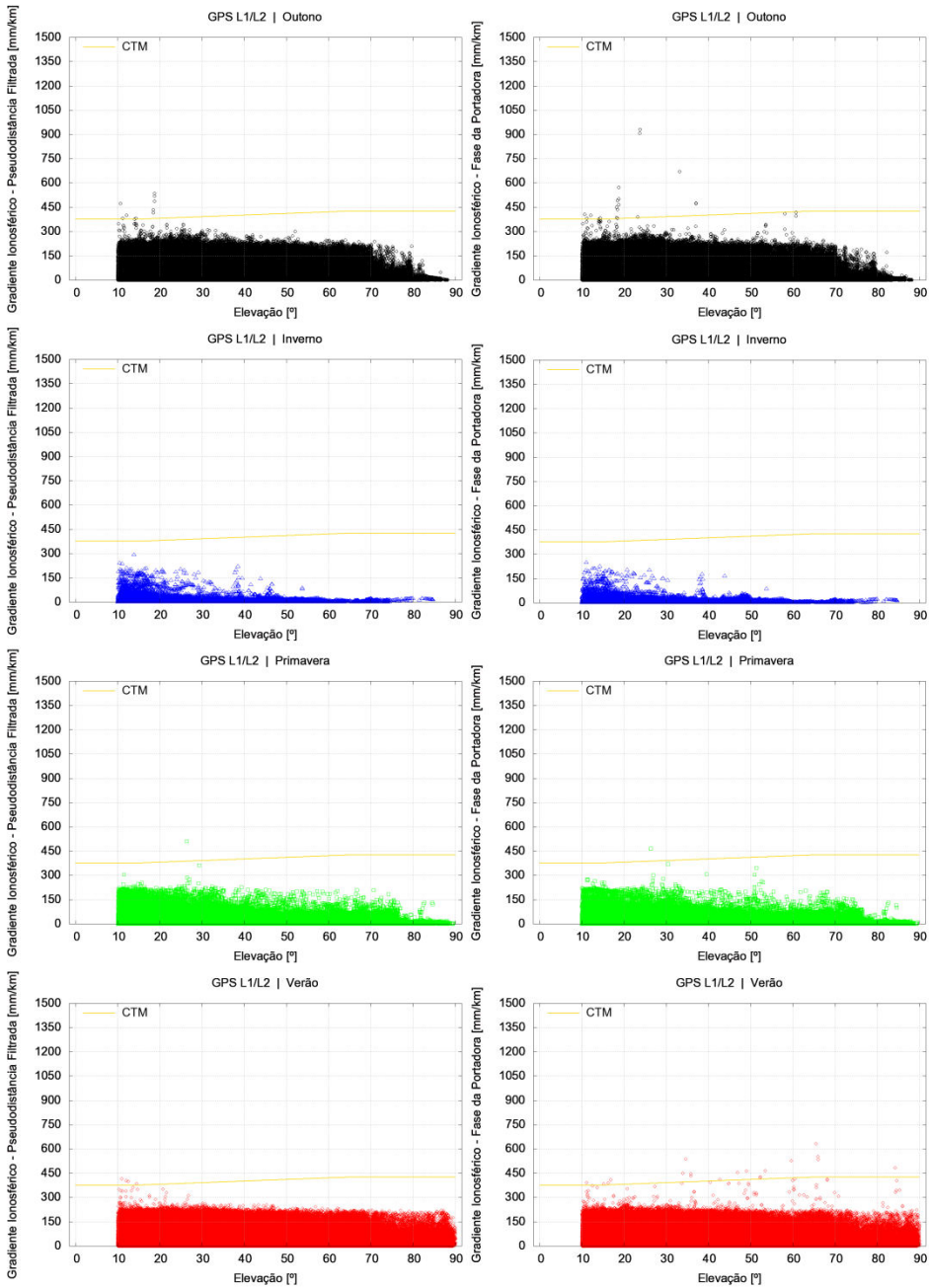
Gradiente x Elevação



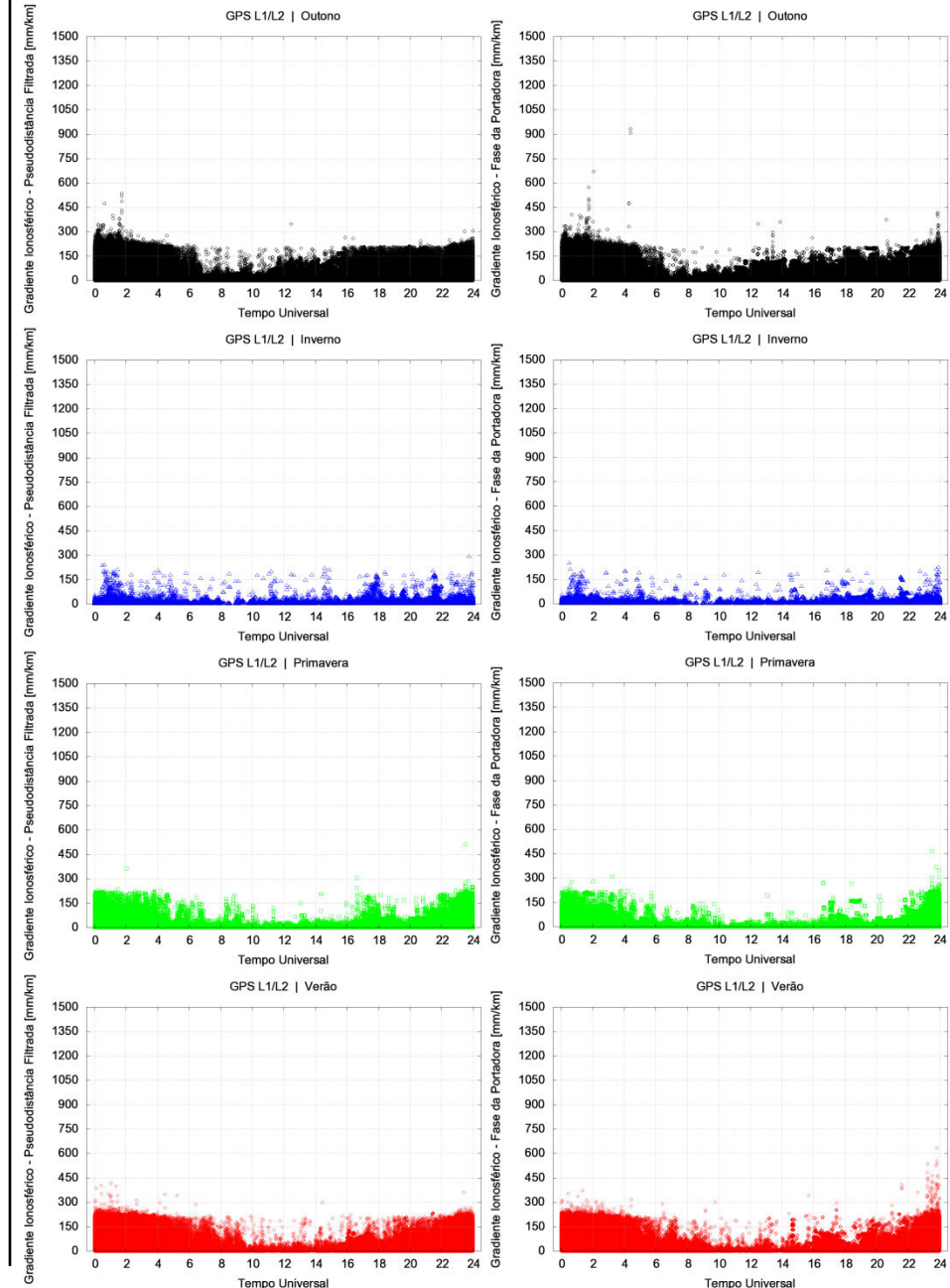
Gradiente x Tempo Universal



Gradiente x Elevação



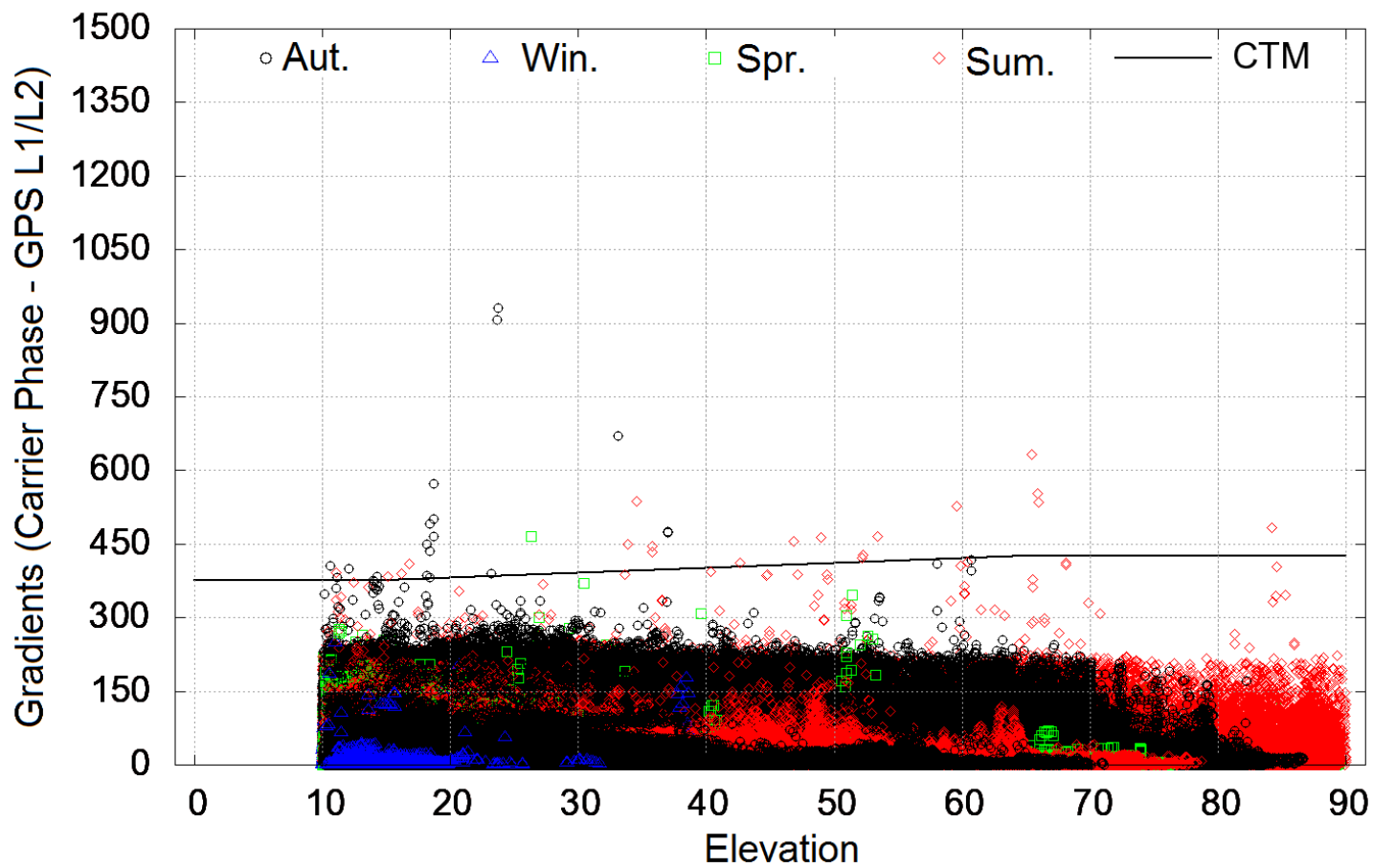
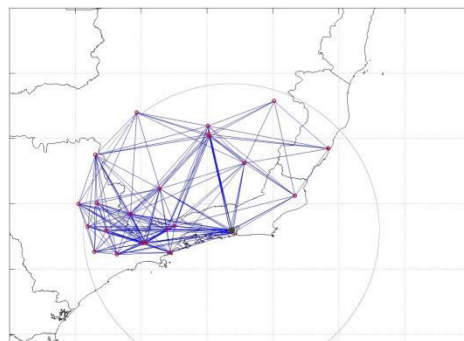
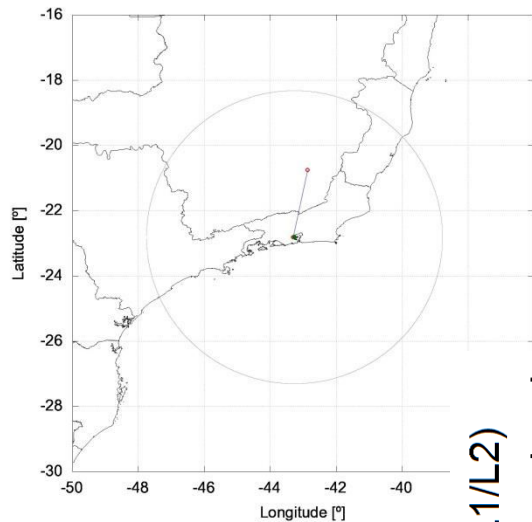
Gradiente x Tempo Universal



Rio de Janeiro International Airport (SBGL/GIG)

Pares de Estações | 20/03/2001 | Raio: 500 km | DM: 400 km

Pares de Estações | 21/06/2016 | Raio: 500 km | DM: 400 km



Se os gradientes do modelo de risco de uma região forem inferiores aos limites do *CONUS Threat Model*

Pode-se certificar que a estação GBAS SLS-4000 da Honeywell atende os requisitos de integridade para aproximações precisas de aeronaves na respectiva região

Time Windows Exceptions for GBAS in Brazil CAT-II

Time and Elevation Window Exceptions (L1/L2), Carrier Phase	Seasons			
	Autumn	Winter	Spring	Summer
Brazilian International Airports				
Sao Paulo (SBGR/GRU)	22h-05h UT	-	22h-05h UT	22h-05h UT
Rio de Janeiro (SBGL/GIG)	<u>elev 10°- 37°</u>	-	23h-24h UT	21h-24h UT
Brasilia (SBBR/BSB)	22h-04h UT	-	22h-02h UT	22h-03h UT
Porto Alegre (SBPA/POA)	-	-	-	-
Recife (SBRF/REC)	-	-	-	21h-24h UT

14ª SNCT – 23 a 29 de outubro de 2017 – “A Matemática está em Tudo”



Final Comments

- GNSS-NavAer is under development with several challenges;
- Support from FAPESP, CNPq and CAPES;
- PhD and Master grants available; and
- Other results are already available and will be presented in another opportunity.

To follow GNSS-NavAer go to:

<http://www.fct.unesp.br/#!/pesquisa/inct-gnss-navaer/>


Faculdade de Ciências e Tecnologia

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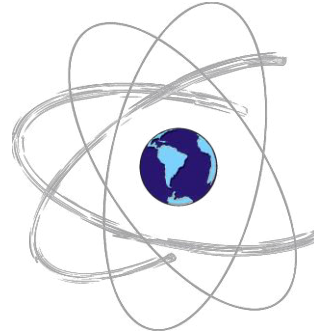
Apresentação

INICIO SOBRE MEMBROS POSTAGENS PUBLICAÇÕES CONTATO



Atualizada em 17/10/2017 às 11:05 - Responsável: Prof. Milton Hirokazu SHimabukuro

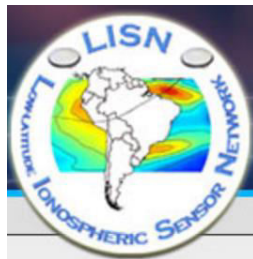
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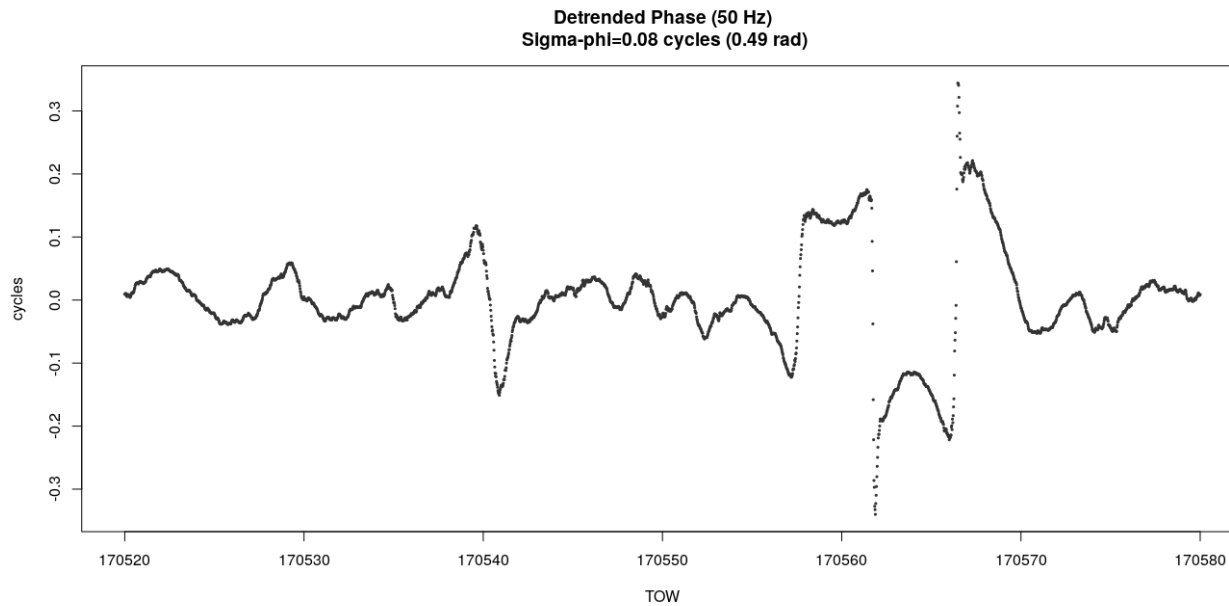
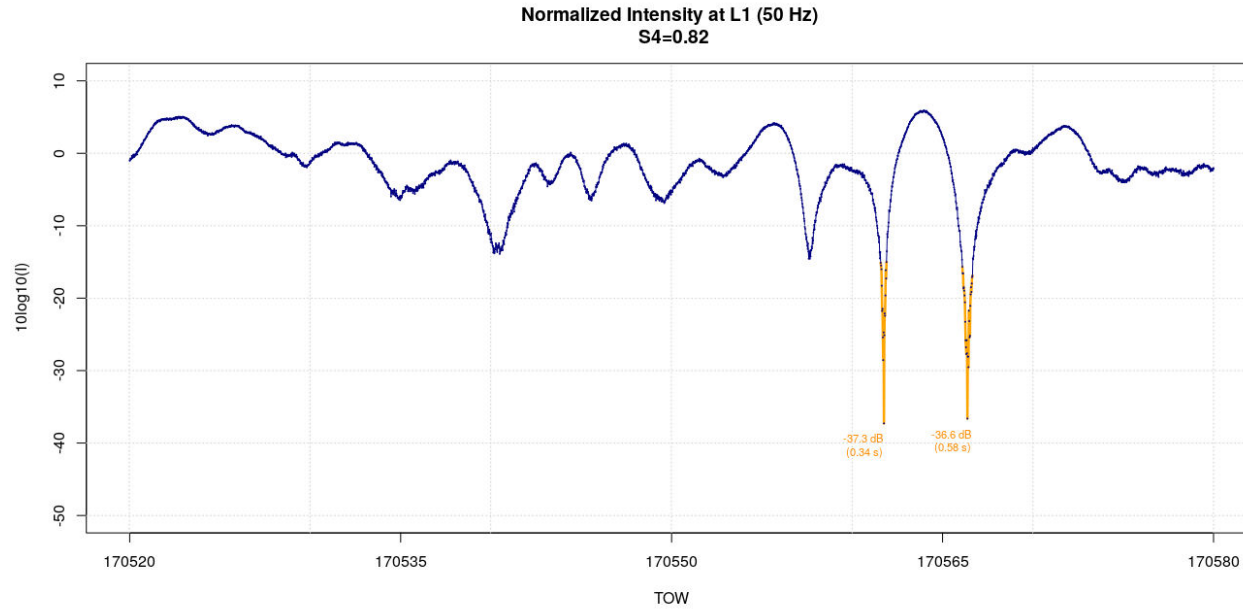
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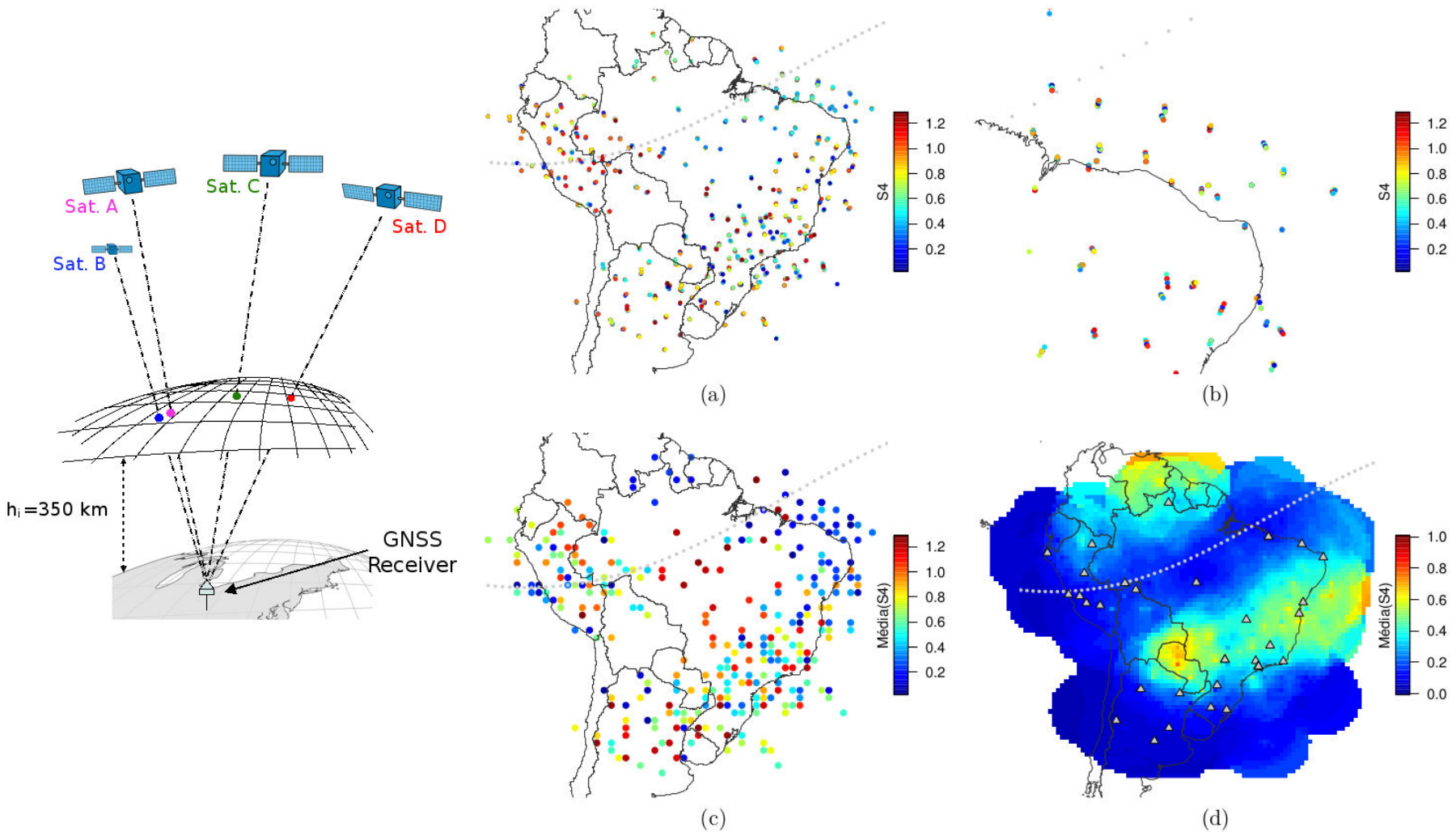
GNSS Signal Fading Analysis

- The IS monitoring stations provide data to support research regarding the performance of the GNSS receivers under scintillation occurrence;
- The analysis of fading duration and fading depth together with the effects on the GNSS observables
 - allow to investigate the performance of the receiver DLL/PLL;
- Such investigations aim to improve robustness of GNSS receivers against scintillations.

GNSS Signal Fading Analysis

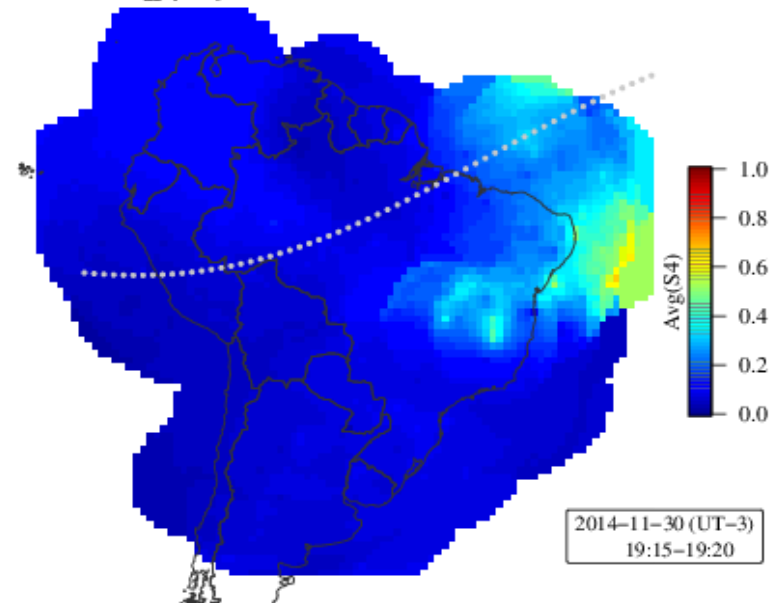
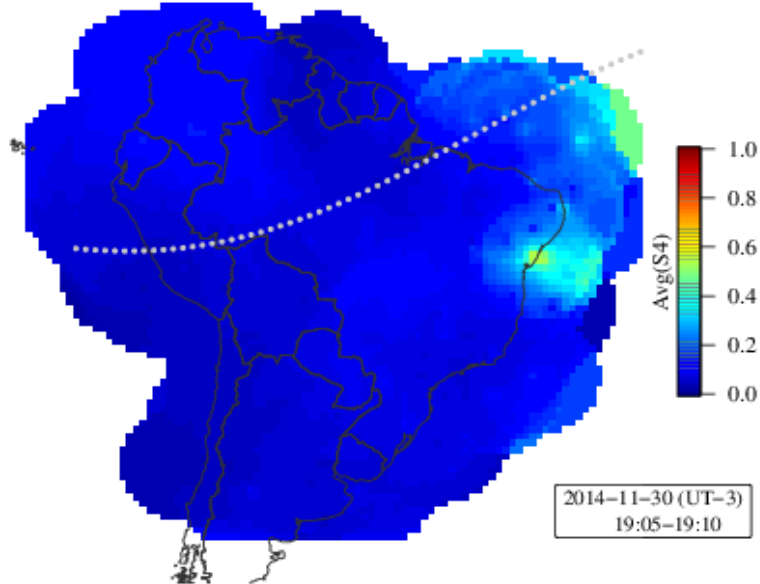
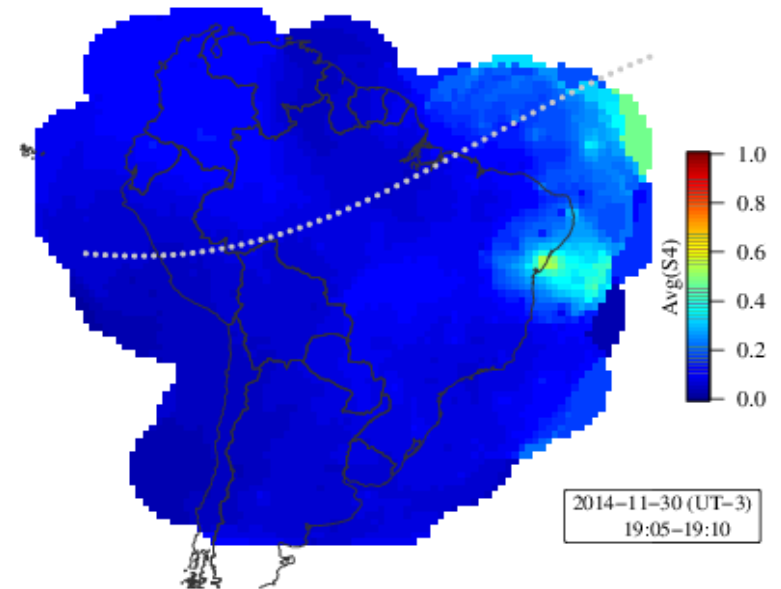
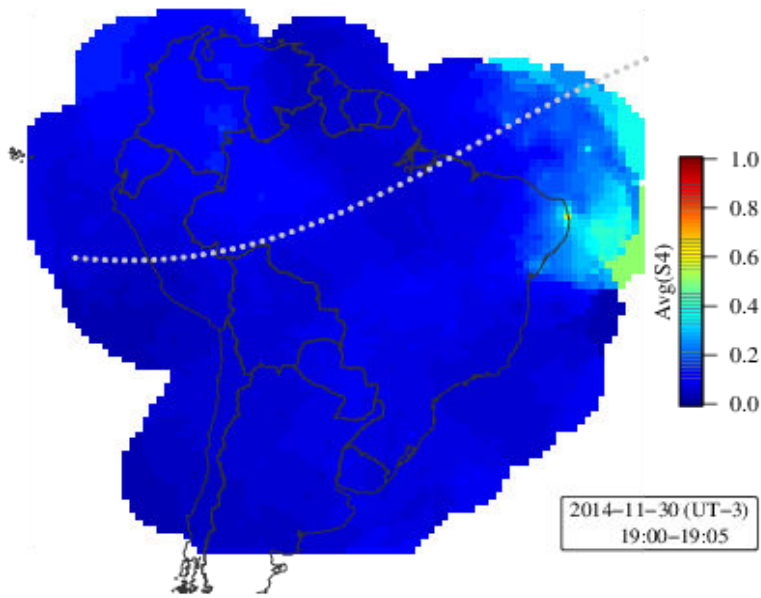


Research on observed scintillation maps to describe scintillation activity (S4)



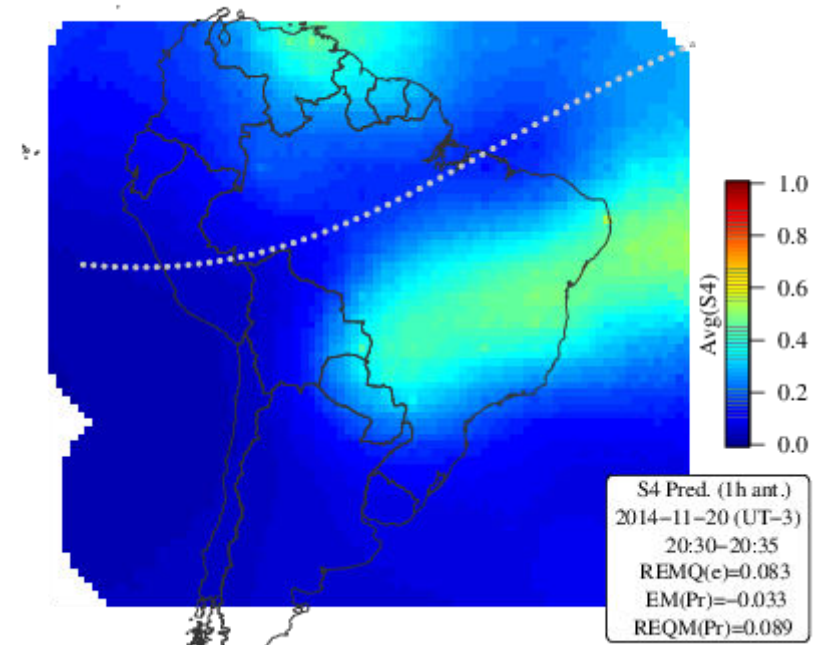
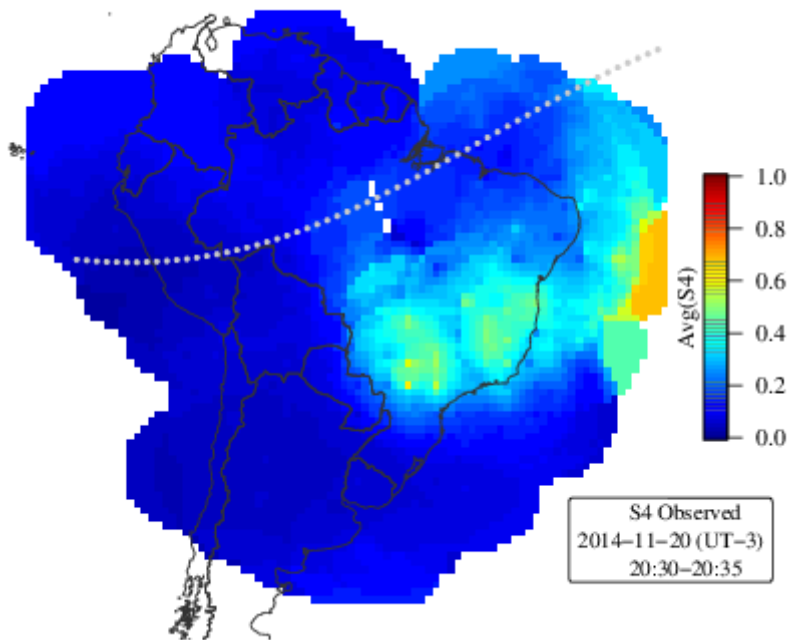
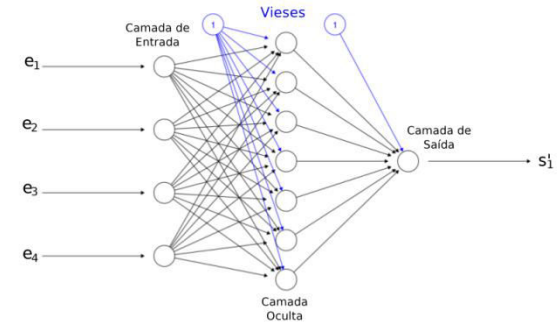
Vani (2018)

Ex: Observed S4 maps

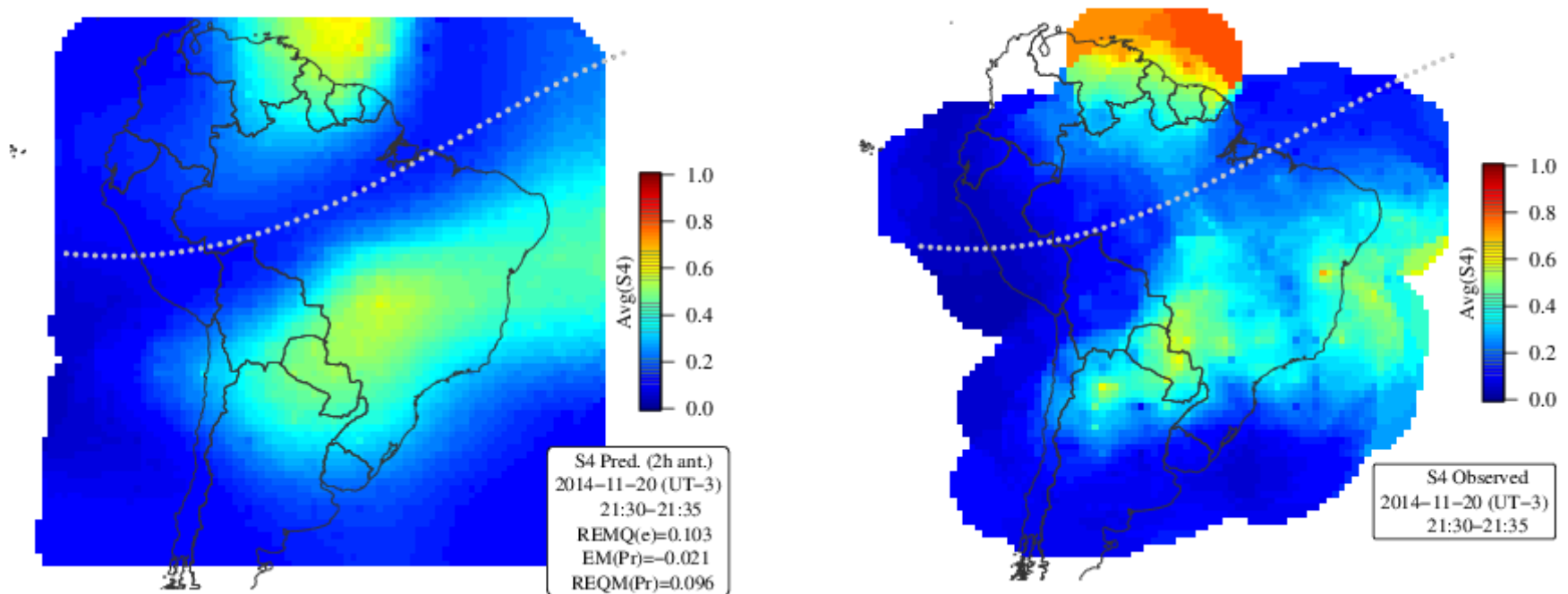


Research on scintillation forecast (predicted S4)

Artificial Neural Network (ANN) Model



Ex: Prediction results



- Filtering approach (incorporate new data when available)
- Support for planning tasks to applications like surveying
- Future:
 - Operation in near real-time with new receivers
 - Develop products (corrections and/or alerts for positioning)