

I Workshop da RBMC

Mapas da ionosfera com dados da RBMC: *comparação de modelos*

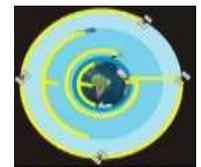
Fabricio S. Prol – *Mestrando PPGCC*

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FCT/UNESP – Presidente Prudente, SP

São Paulo, 19 de junho de 2013



SUMÁRIO

- Posicionamento GNSS
- GNSS x Ionosfera
- Comparação entre modelos da ionosfera
 - Mapas
 - Análises estatísticas
- Considerações finais

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- Posicionamento GNSS
- GNSS x Ionosfera
- **Comparação entre modelos da ionosfera**
 - Mapas
 - Análises estatísticas
- Considerações finais

Qual a discrepância dos valores de TEC entre os modelos que utilizam dados da RBMC?



SUMÁRIO

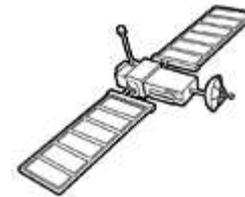
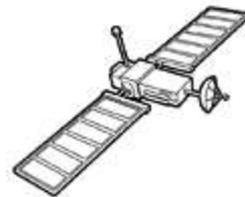
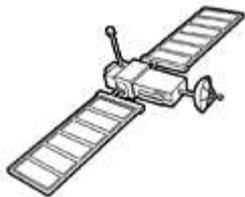
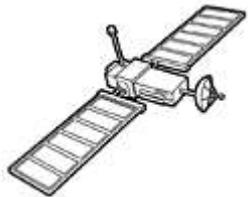
- Posicionamento GNSS
- GNSS x Ionosfera
- **Comparação entre modelos da ionosfera**
 - Mapas
 - Análises estatísticas
- Considerações finais

Qual a compatibilidade destes modelos com um modelo climatológico?



Posicionamento GNSS

- Densificação nos sistemas GNSS
 - GPS, GLONASS, GALILEU, BEIDOU
 - Densificação nos Sistemas de Controle Ativo (SCA)
 - RBMC/RIBaC, IGS, rede GNSS-SP
- Levantamentos geodésicos mais acurados.
- A acurácia obtida depende das observáveis do sistema (fase da onda portadora e pseudodistância), que são afetadas diretamente por diversos erros sistemáticos.

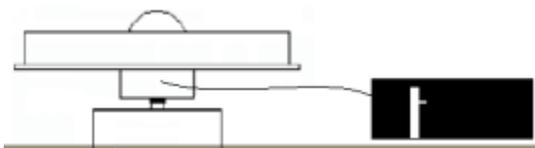


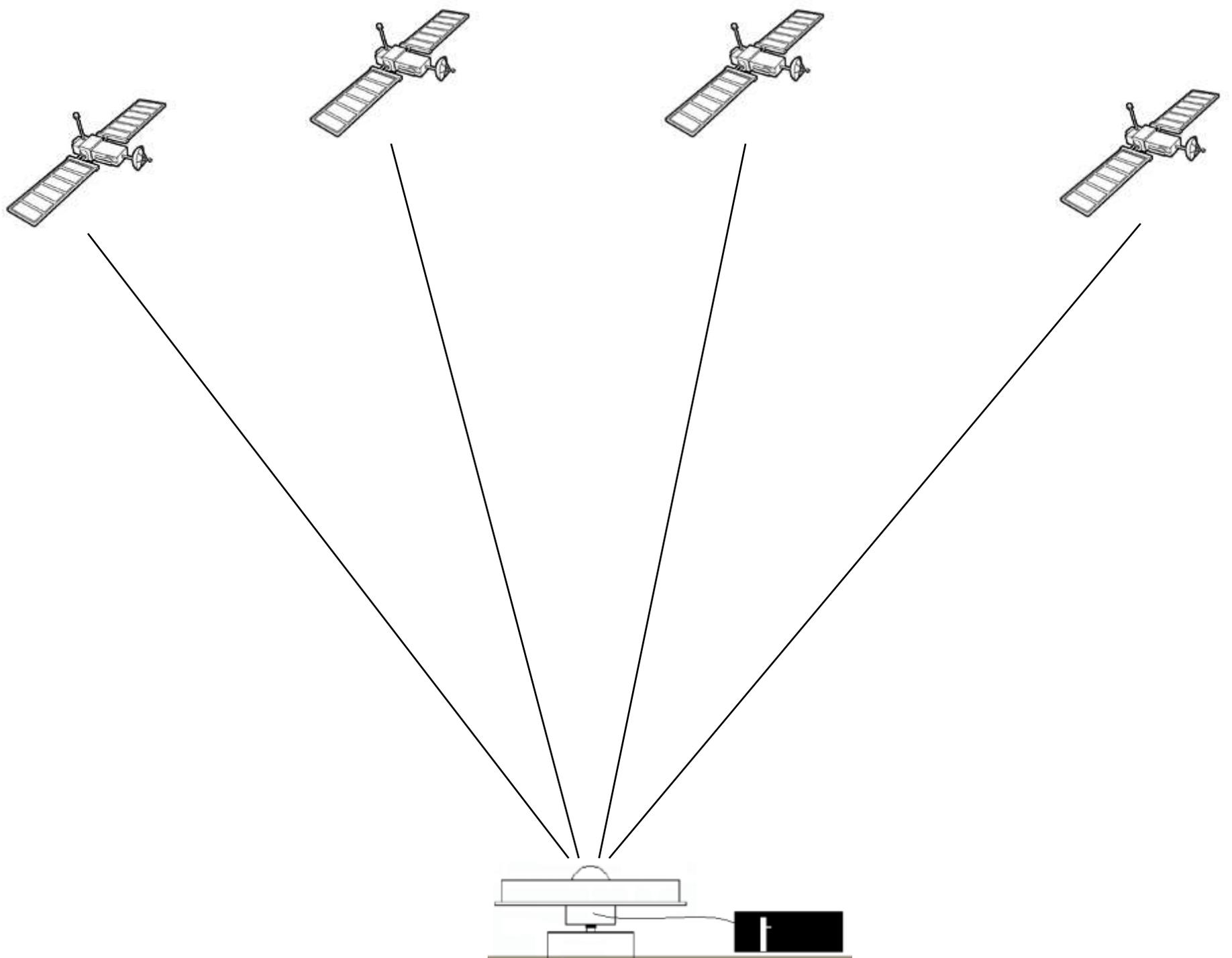
Coordenadas Conhecidas

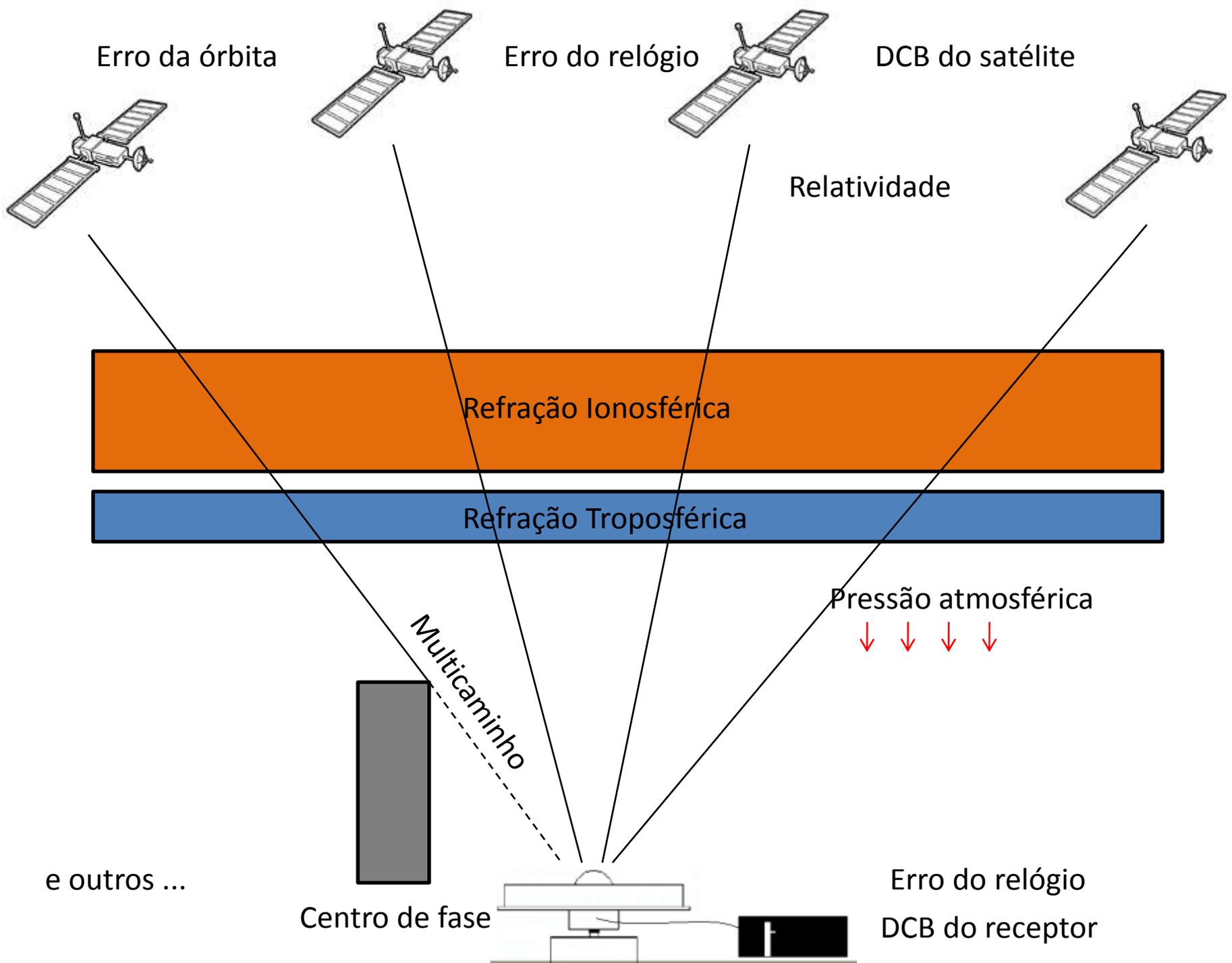
Estações de referências
permitem modelar os
erros sistemáticos

SCA

Coordenadas Conhecidas







Erro da órbita

Erro do relógio

DCB do satélite

Relatividade

Refração Ionosférica

Refração Troposférica

Pressão atmosférica

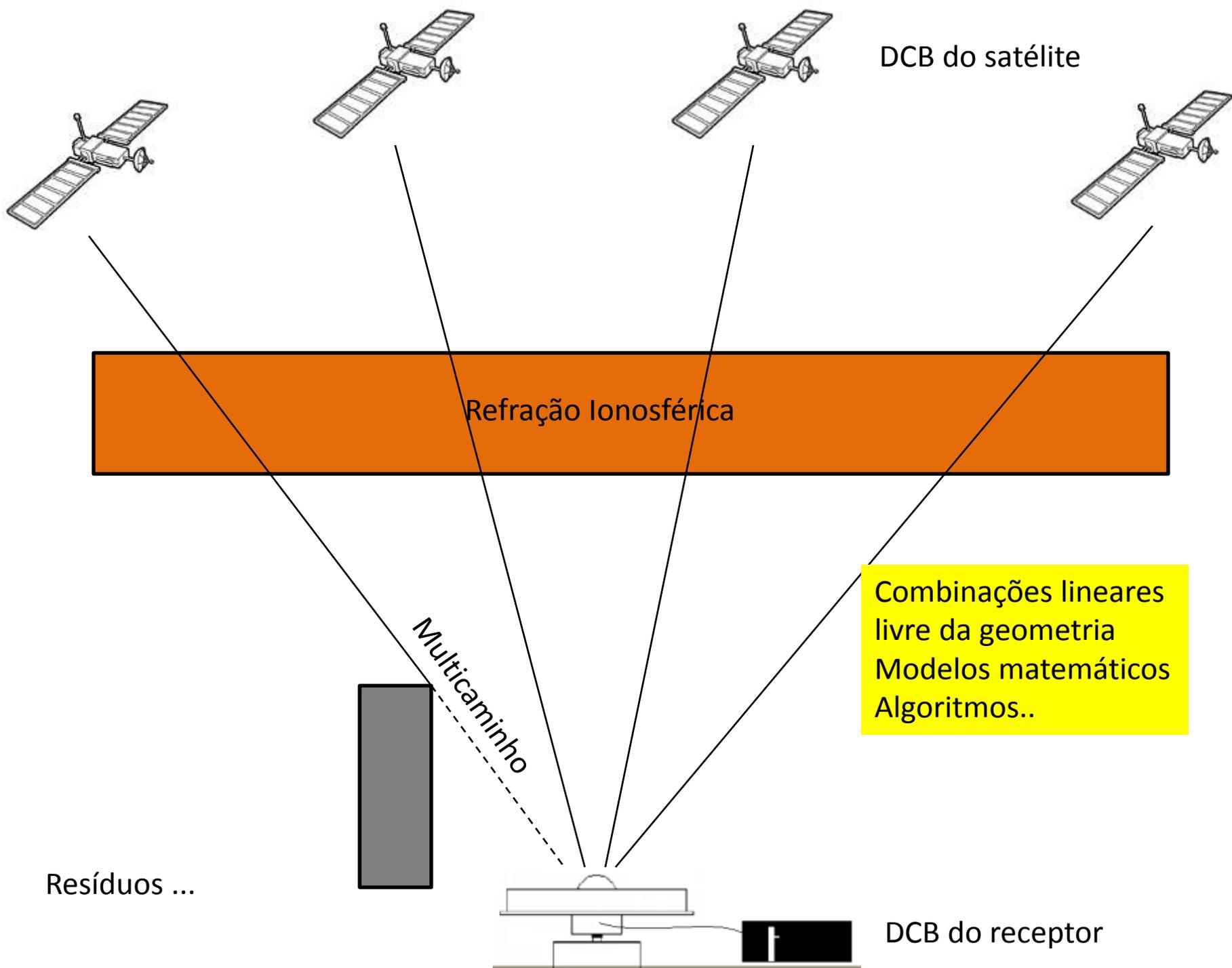
Multicaminho

e outros ...

Centro de fase

Erro do relógio

DCB do receptor



DCB do satélite

Refração Ionosférica

Combinações lineares
livre da geometria
Modelos matemáticos
Algoritmos..

Multicaminho

Resíduos ...

DCB do receptor

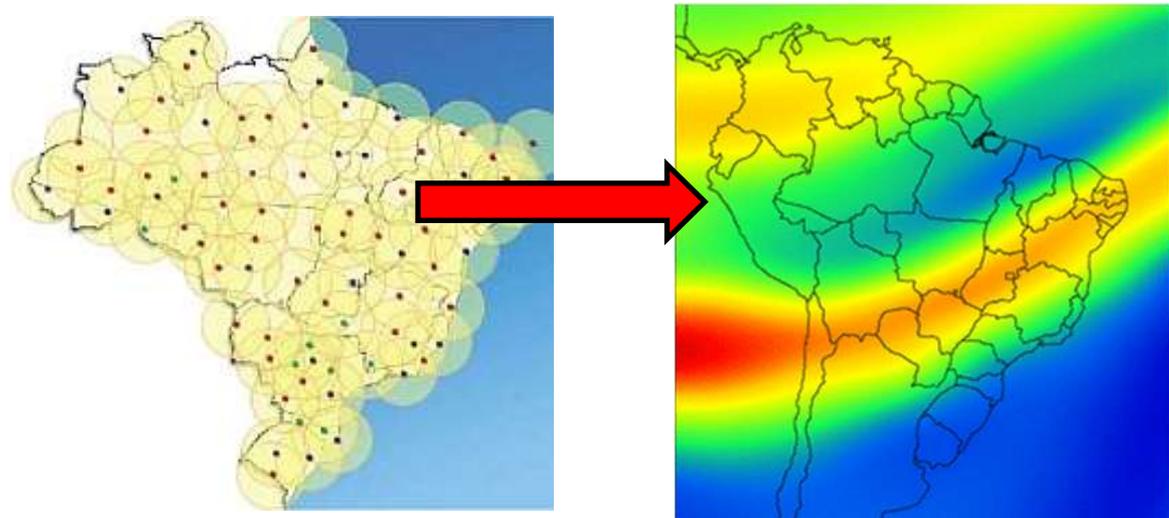
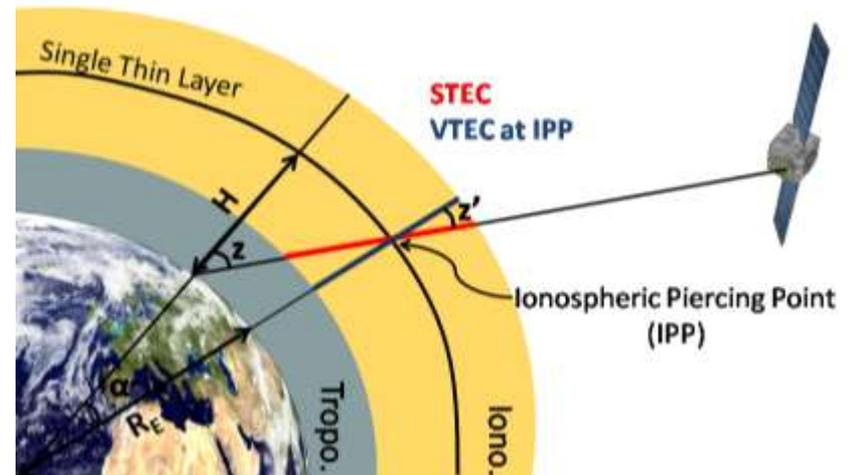
GNSS x Ionosfera

O erro devido à ionosfera é proporcional ao TEC. Receptores de dupla frequência permitem efetuar combinações lineares e calcular o TEC.

$$1 \text{ TECU} = 1 \times 10^{16} \text{ el/m}^2$$

$$L1 \cong 0,16\text{m}$$

$$L2 \cong 0,27\text{m}$$



Mapas Avaliados

- IGS → International GNSS Service

Ionospheric Working Group, desde 1998

CODE



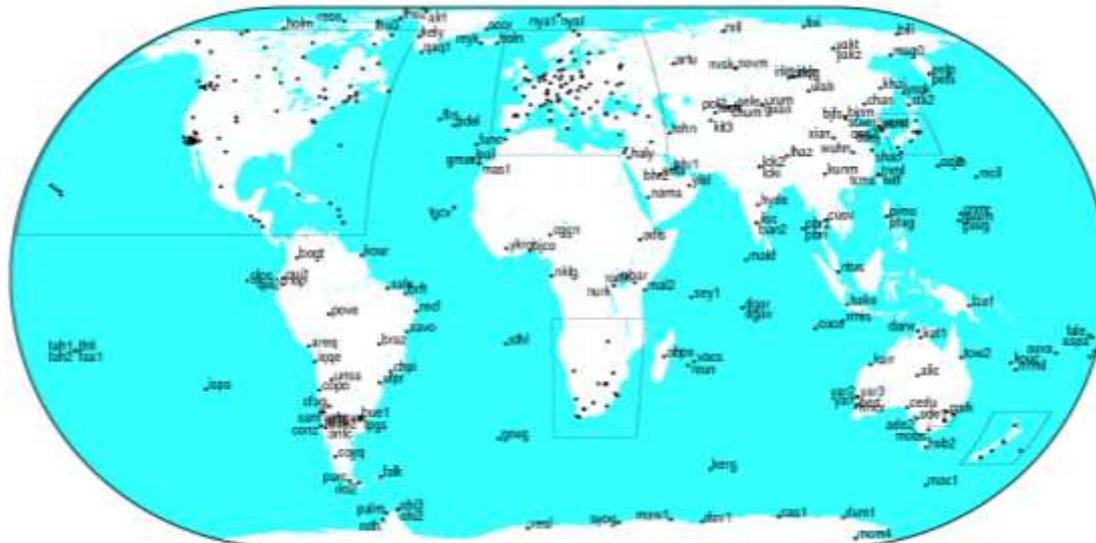
ESOC



JPL

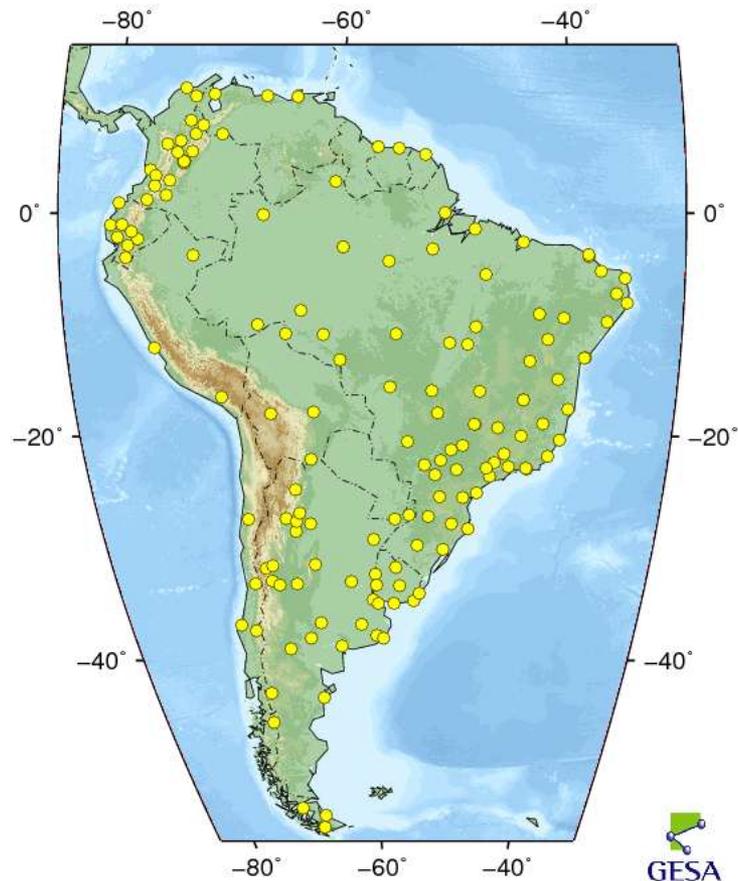


UPC



Mapas Avaliados

- LPIM → La Plata Ionospheric Model
- Desenvolvido na Universidade de La Plata e é utilizado pelo Centro de Análise Ionosférica do SIRGAS para produzir mapas de VTEC para a América do Sul



Mapas Avaliados

- MODION → Modelo regional da Ionosfera
- Desenvolvido na FCT/UNESP



Mapas Avaliados

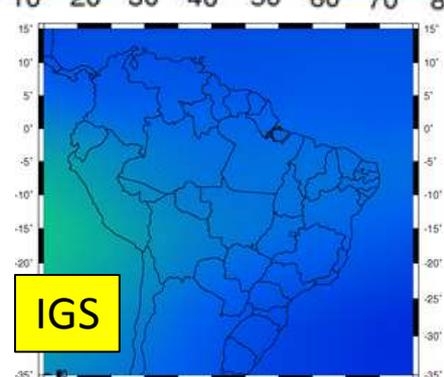
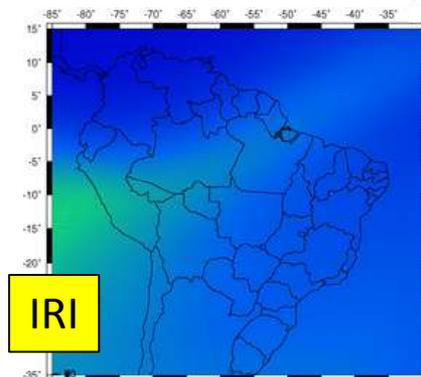
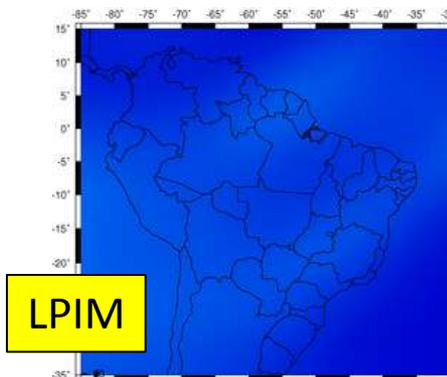
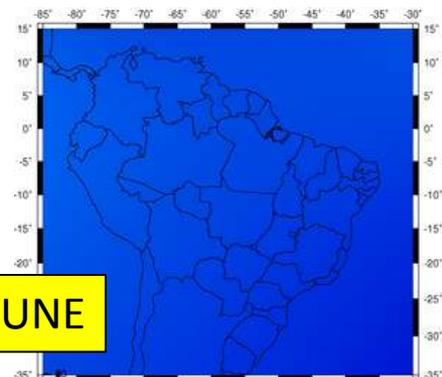
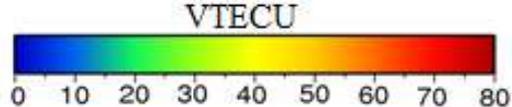
- IRI → International Reference Ionosphere
- Mantido pela COSPAR e URSI
- As principais fontes de dados provêm de uma rede mundial de ionossondas, radares de espalhamento incoerente, as sondas ISIS e Alouette e instrumentos acoplados em satélites e foguetes espaciais
- Descreve a ionosfera em função da densidade de elétrons, íons, temperatura, composição iônica e velocidade do plasma

Experimentos

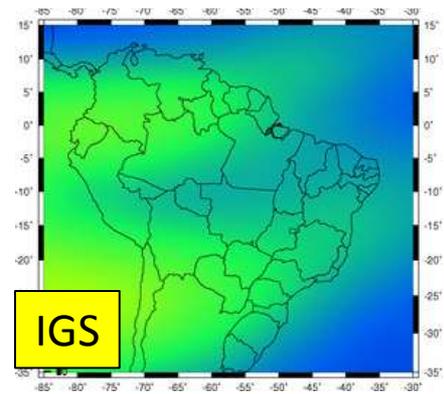
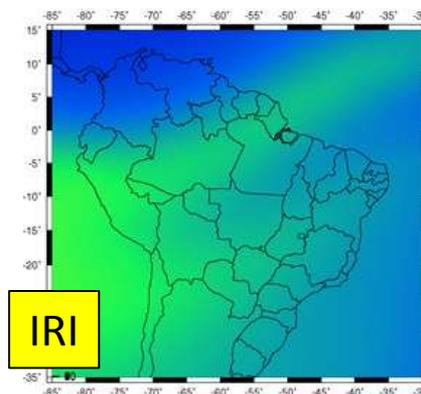
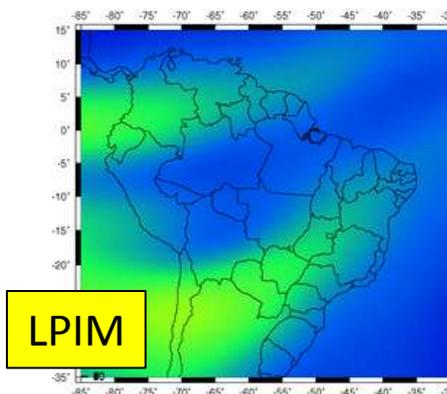
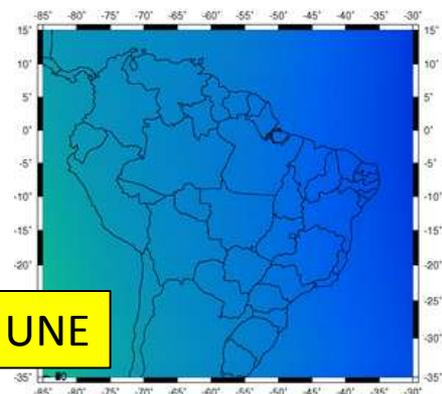
Três épocas de interesse:

- **Baixa Atividade Ionosférica** → 04/01/2009
- **Moderada Atividade Ionosférica** → 28/01/2011
- **Alta Atividade Ionosférica** → 07/01/2013

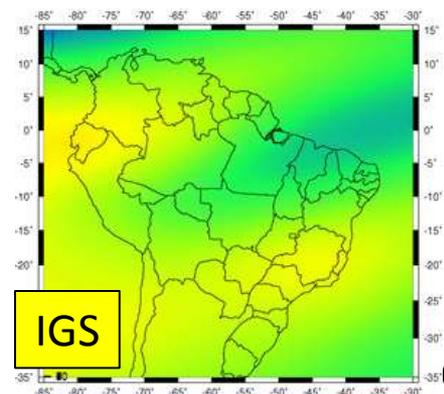
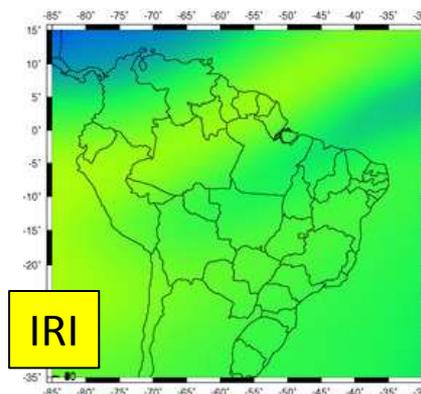
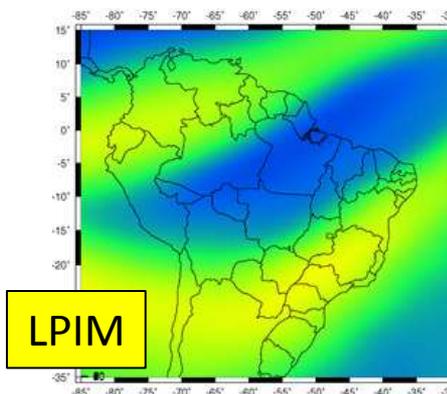
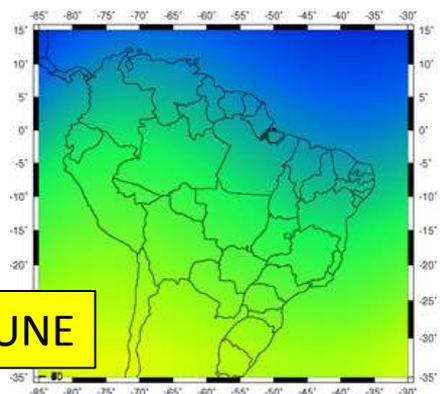
04/01/2009 - BAIXA ATIVIDADE



28/01/2011 - MODERADA ATIVIDADE



07/01/2013 - ALTA ATIVIDADE



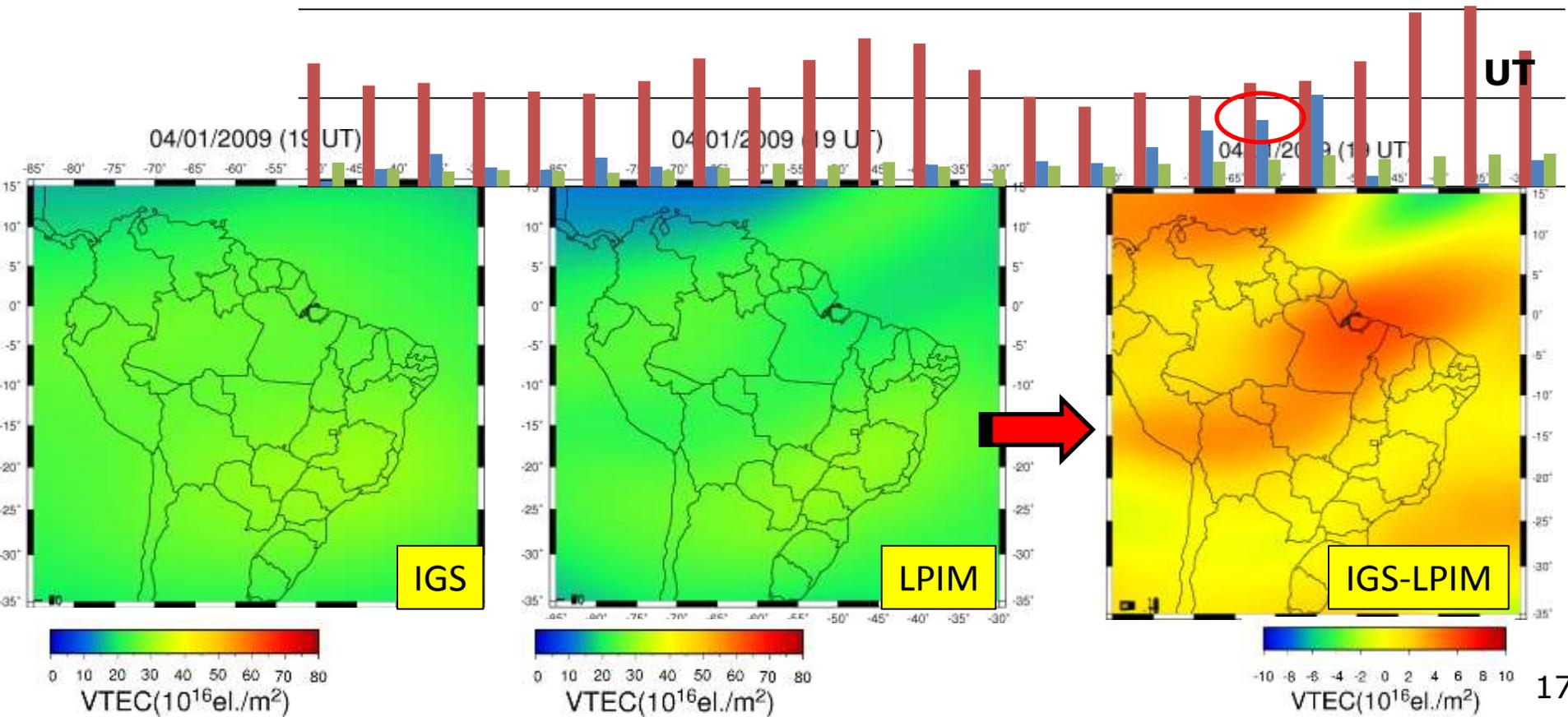
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LPIM

BAIXA ATIVIDADE

TECU

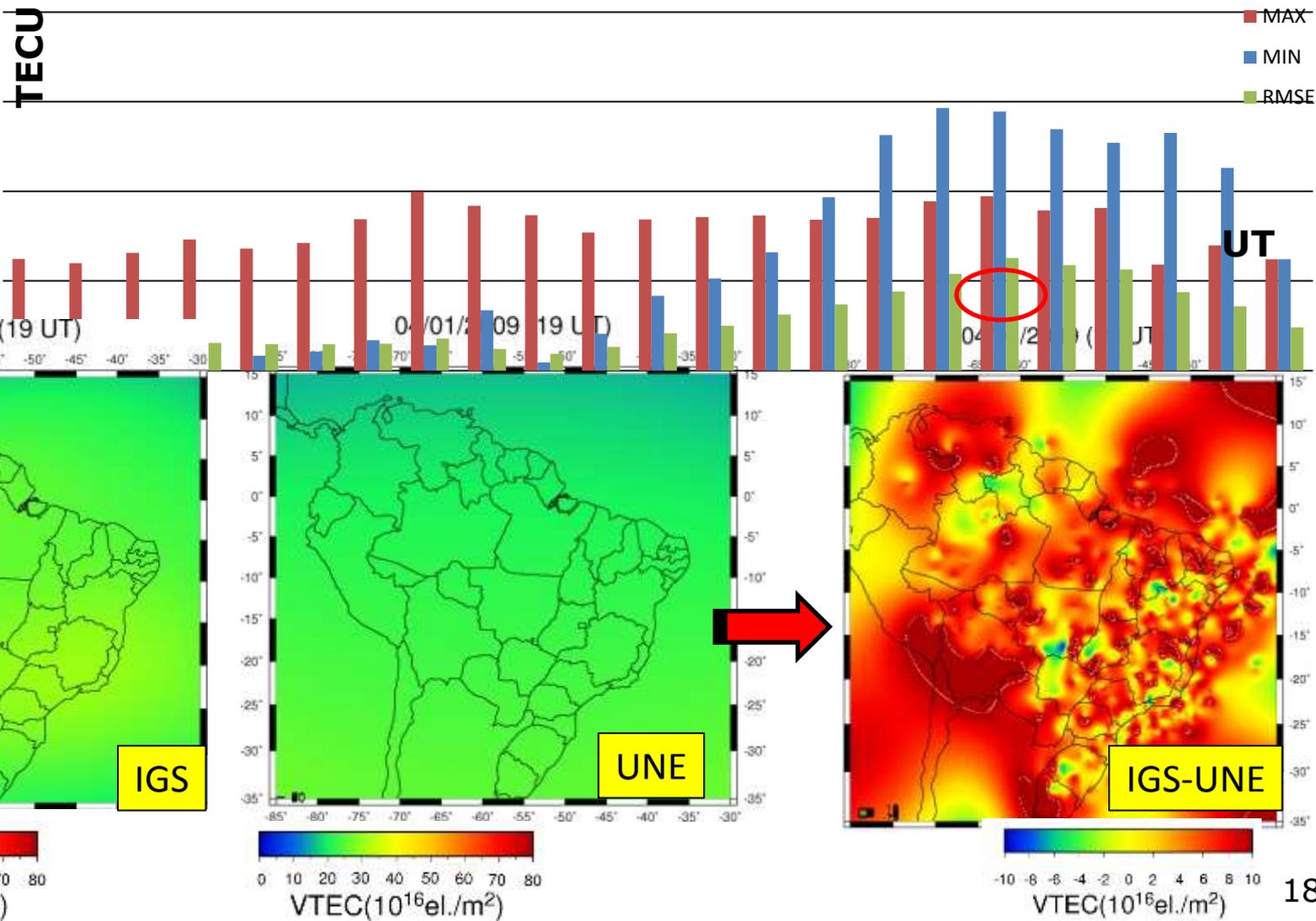
MAX
MIN
RMSE



04/01/2009

MODION

BAIXA ATIVIDADE



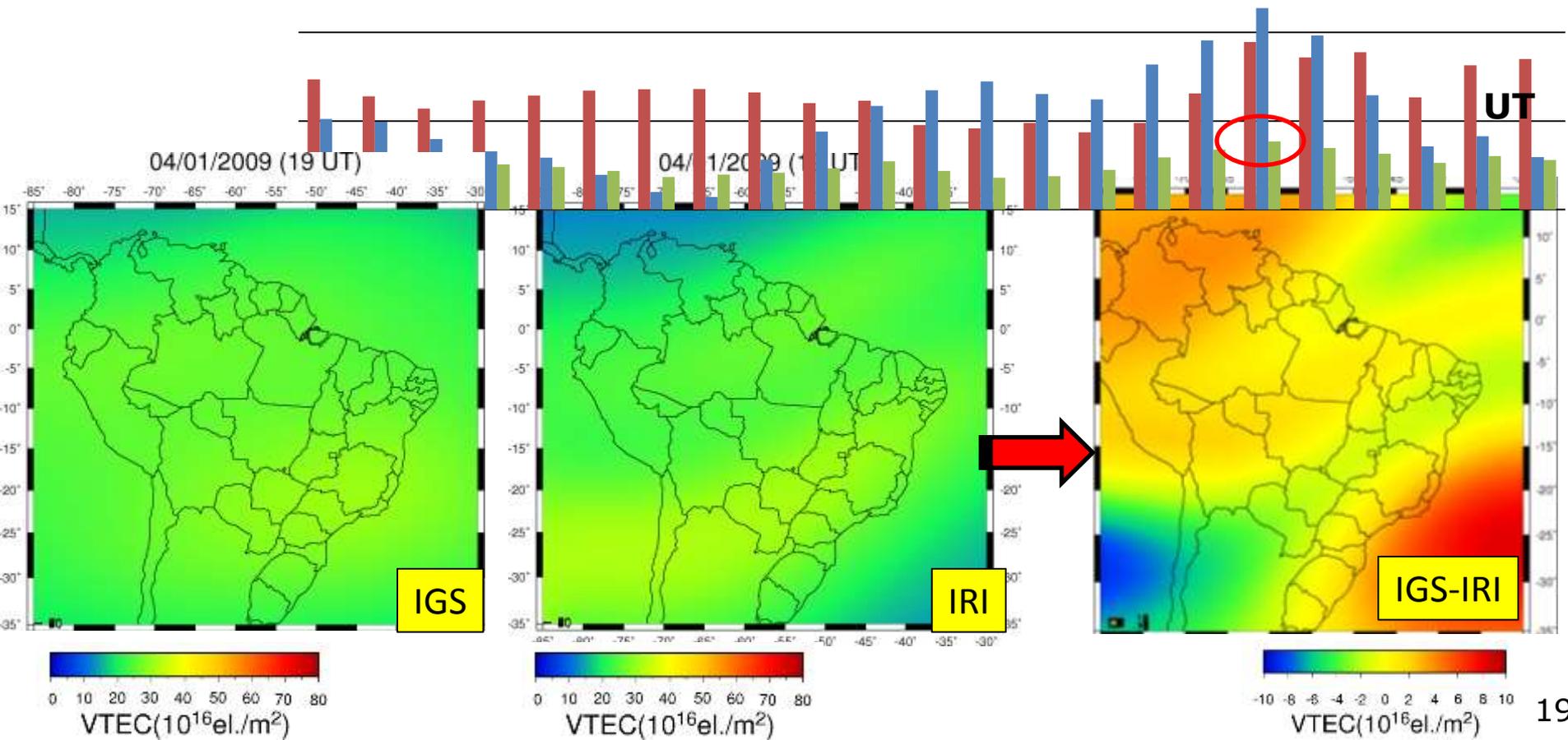
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IRI-2007

BAIXA ATIVIDADE

TECU

MAX
MIN
RMSE



28/01/2011

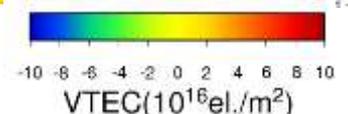
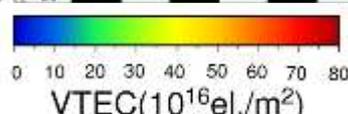
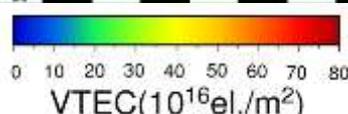
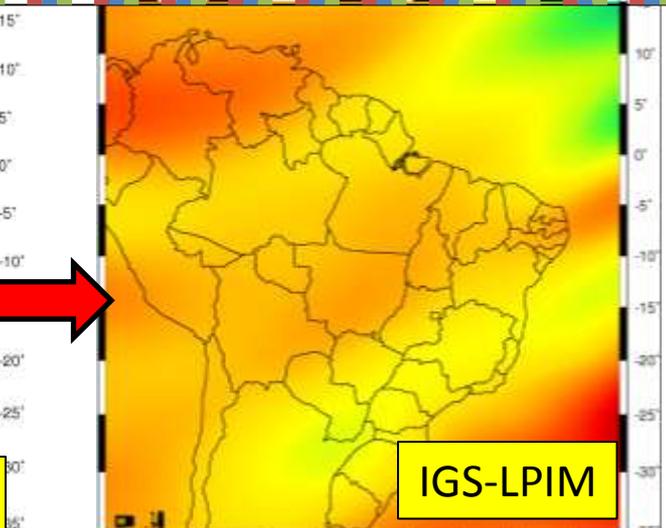
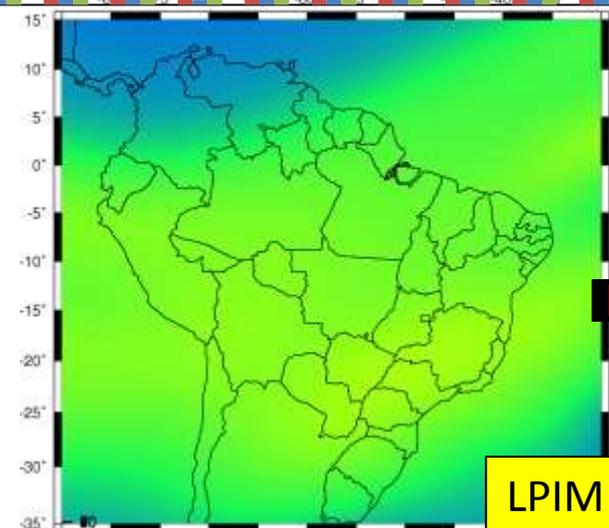
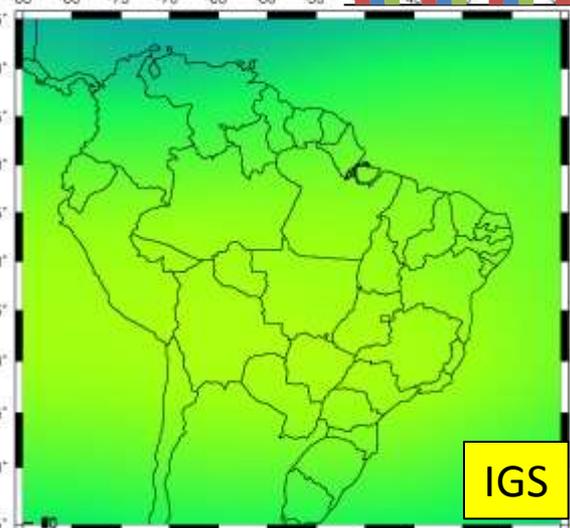
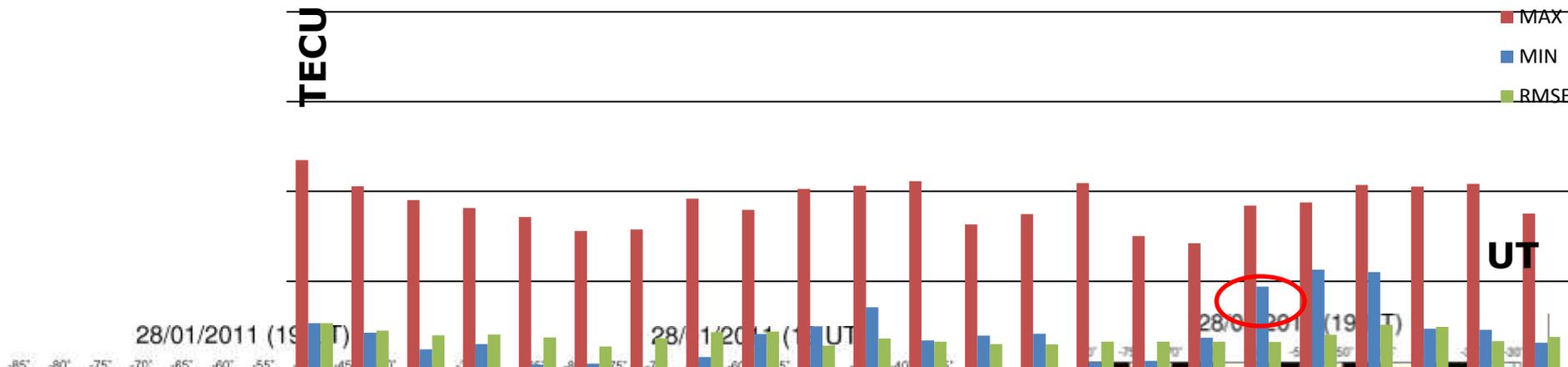
MODERADA ATIVIDADE

LPIM

TECU

MAX
MIN
RMSE

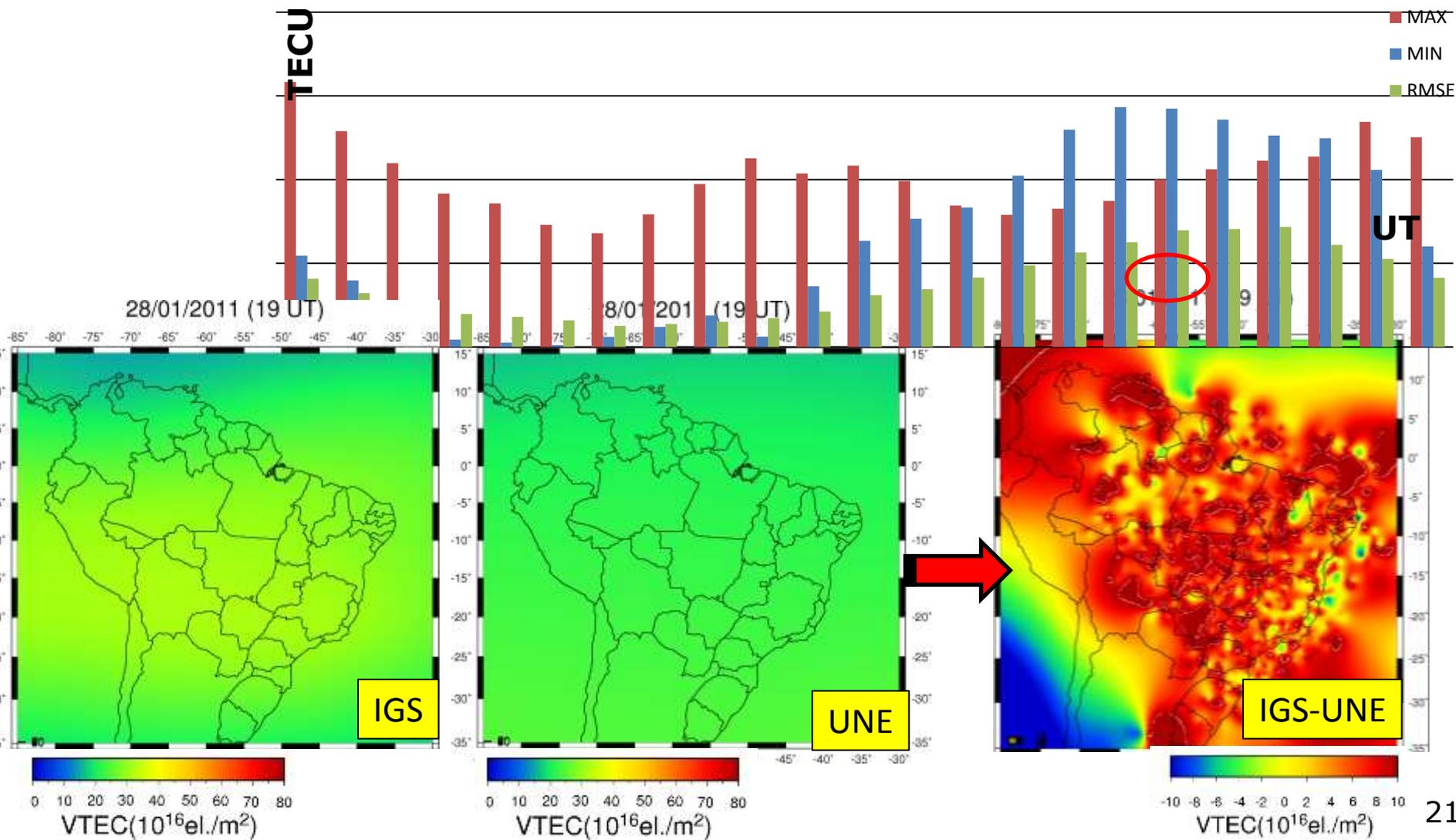
UT



28/01/2011

MODERADA ATIVIDADE

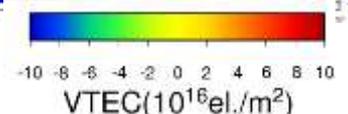
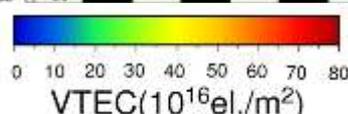
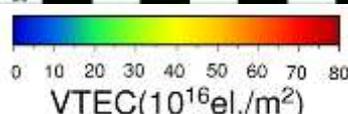
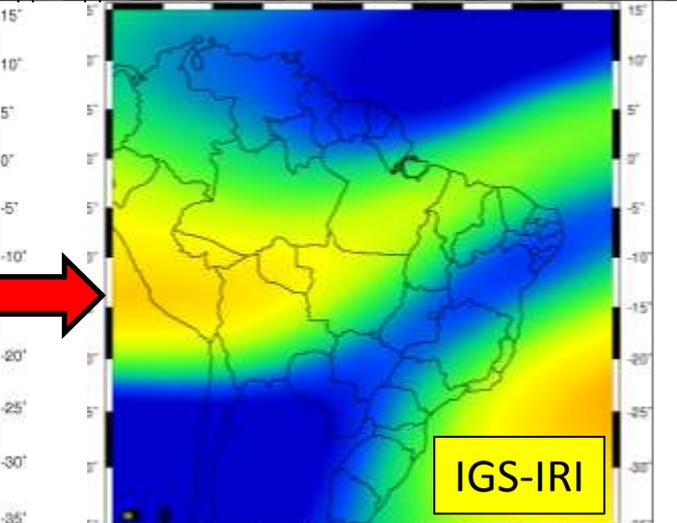
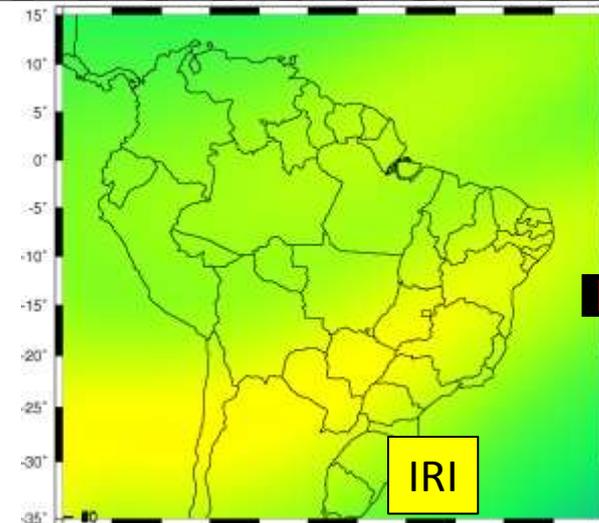
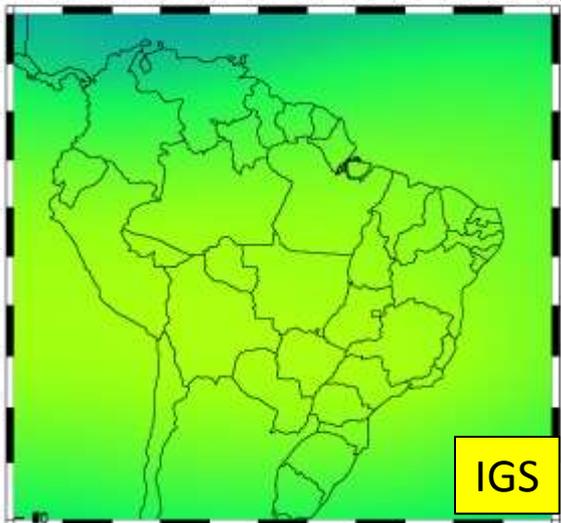
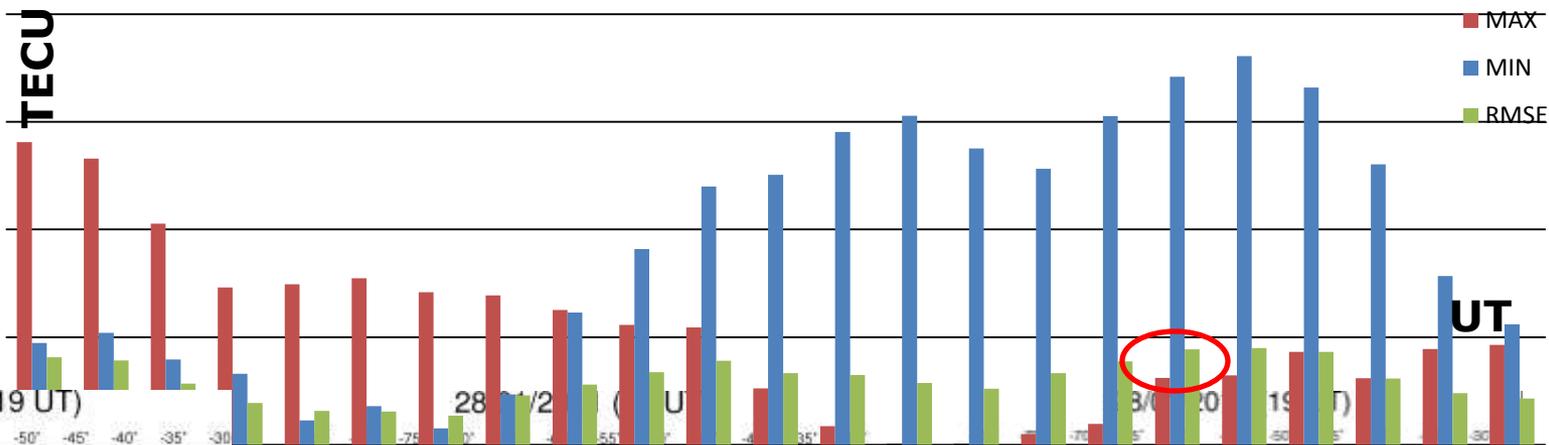
MODION



28/01/2011

MODERADA ATIVIDADE

IRI-2007



ALTA ATIVIDADE

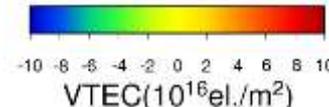
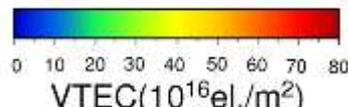
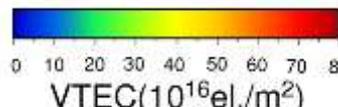
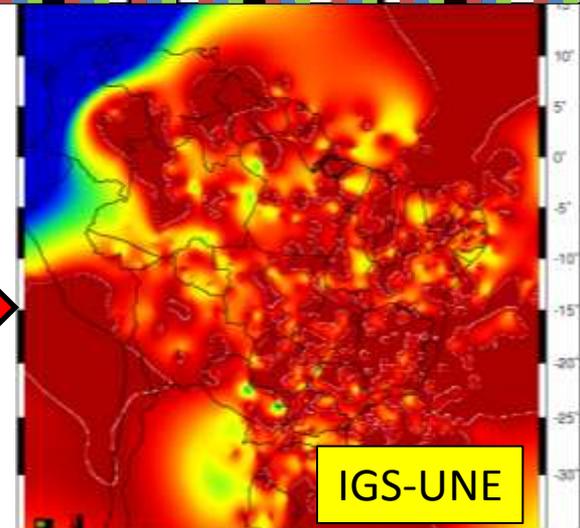
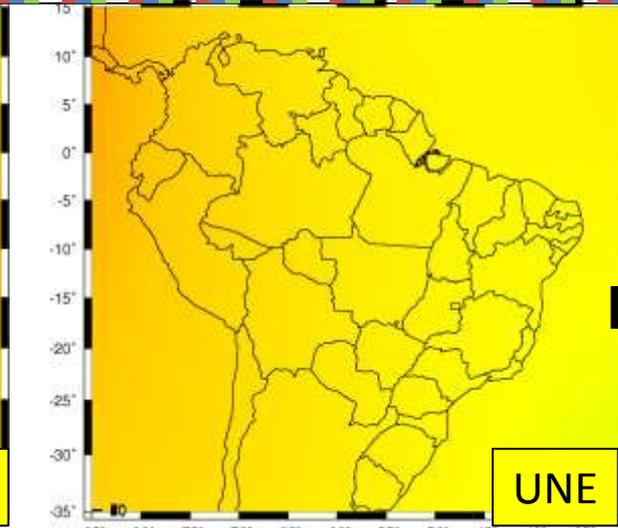
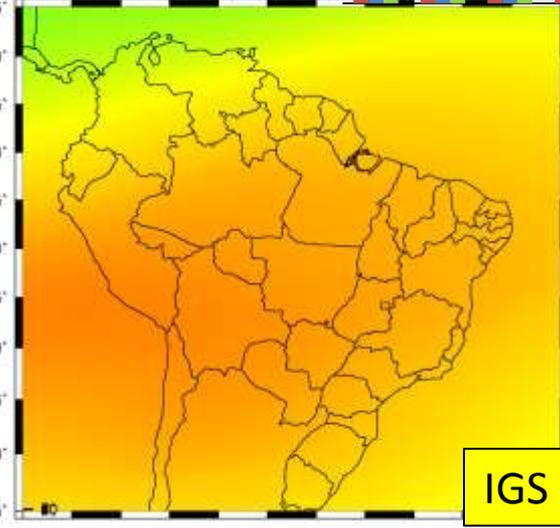
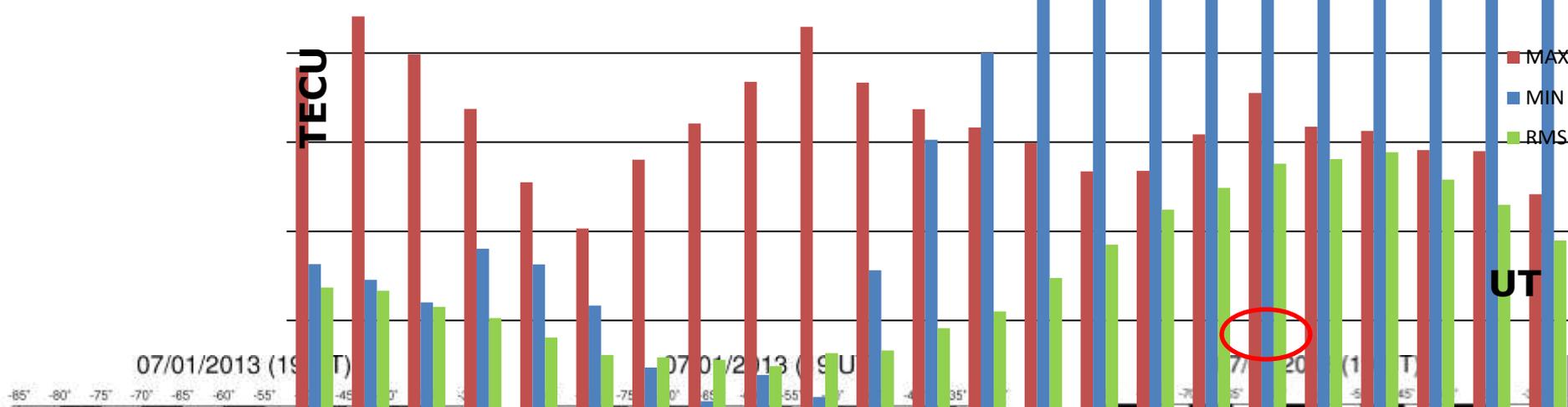
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MODION

TECU

MAX
MIN
RMSE

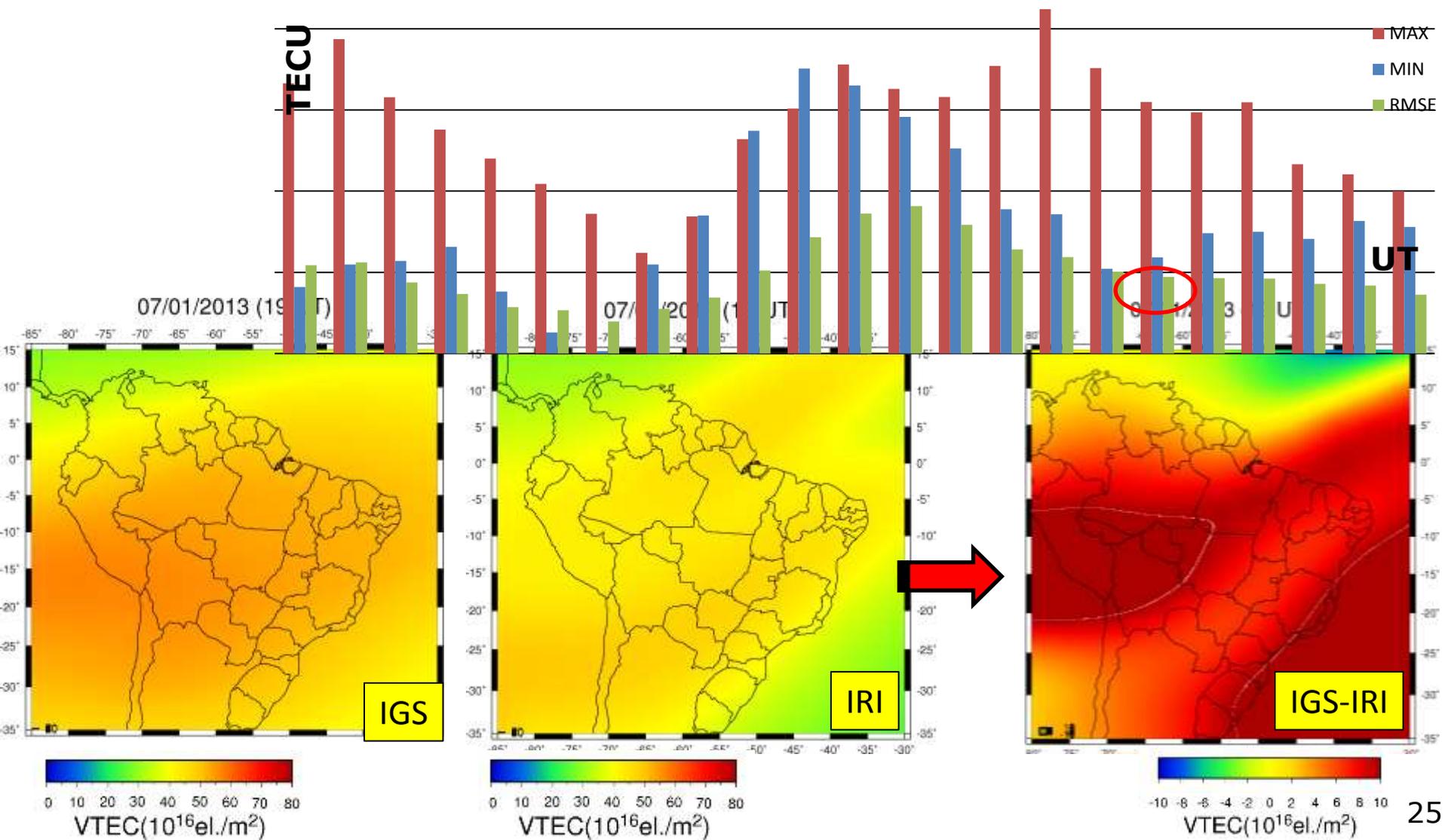
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ALTA ATIVIDADE

07/01/2013

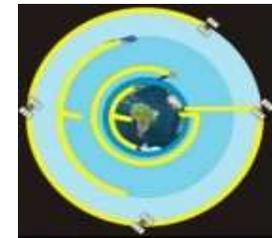
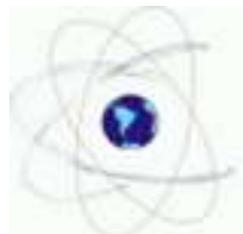
IRI-2007



Considerações Finais

- Tendo os GIM's do IGS como modelo de referência, conclui-se:
- LPIM →
 - RMSE menor que 5 TECU
 - Sub-estima os valores de TECU em todas as épocas do experimento
 - Representa a Anomalia Equatorial (AE)
- MODION →
 - RMSE menor que 15 TECU
 - Sub-estima os valores de TECU para a região brasileira
 - Suaviza a AE
- IRI →
 - RMSE menor que 10 TECU
 - Super-estima os valores de TECU em Baixa e Média Atividade, Super-estima em alta atividade ionosférica
 - Representa a AE

Agradecimentos





"We went to explore the Moon, and in fact discovered the Earth." Eugene Cernan