SIMPOSIO SIRGAS 2021
Del 29 de noviembre al 01 de diciembre de 2021

NEUTRAL ATMOSPHERE DELAY MODELING: RESULTS AND CHALLENGES IN THE BRAZILIAN SCENARIO

T GOUVEIA [1]; J MONICO [1]; D ALVES [1]; L SAPUCCI [2]; F NIEVINSKI [3]

[1]Universidade Estadual Paulista (UNESP), Faculdade de Ciência e Tecnologia (FCT), Departamento de Cartografia, Presidente Prudente - SP

[2]Instituto Nacional de Pesquisas Espaciais (INPE), Centro de Previsão de Tempo e Estudos Climáticos (CPTEC)/Divisão de Desenvolvimento e Modelagem (DMD), Cachoeira Paulista - SP

[3]Universidade Federal do Rio Grande do Sul (UFRGS), Departamento de Geodésia, Porto Alegre – RS

tayna.fgouveia@gmail.com

INTRODUCTION

- The GNSS satellites signals are received in multiple directions characterized by elevation and azimuth angles. When a signal reaches the neutral atmosphere (from the surface to approximately 50 km) at a different angle (ε) of incidence than the normal (or zenith (z)) angle, resulting in a delay (*d*) in signal propagation (Figure 1);
- The delay generates errors in the measurement of pseudodistance and carrier phase of at least 2.5 m (zenithal) and greater than 25 m (horizon), which must be eliminated or minimized;
- The mapping function (*mf*) describes the delay at any elevation angle.

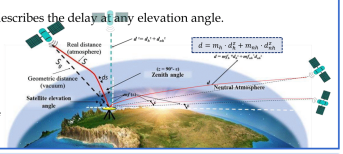


Figure 1 – GNSS signal when propagating in the atmosphere, from satellite to receiver, and the effect of the propagation delay of the GNSS signal carrier wave, and the delay modeling.

DELAY AND THE CHALLENGES IN THE BRAZILIAN CLIMATE

- In calculating the delay, the variability of the constituents of the neutral atmosphere (pressure, temperature and humidity) is considered according to geographic region, time (seasonality and year) and the direction to the satellite (elevation and azimuth);
- Brazilian territory is in the tropical region, and it has great climatic variation, which usually varies according to the regions and seasons of the year (Figure 2). The Brazilian climate has a strong influence of the Amazon rainforest because of the forest emitted gases and water vapor, which cause a variation in the density of gases and water vapor;

Figure 2 – Brazilian climatology, precipitation and temperature variation according to the season and location.

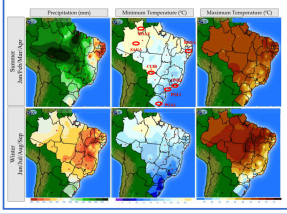
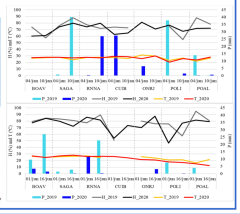


Figure 3 – Humidity (H), Temperature (T) and precipitation (P) to seven different Brazilian regions, in summer (January, 04 and 10) and winter (June, 01 and 16)



NEUTRAL ATMOSPHERE DELAY PRODUCTS

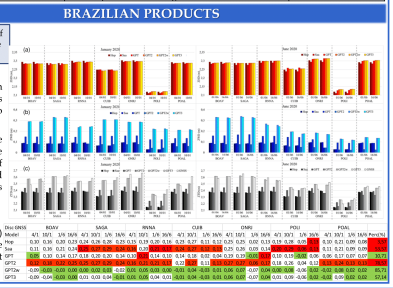
- Different approaches can be applied to obtain information describing the constituents, among the possibilities: radiosondes measurements, numerical weather and climate prediction models, GNSS measurements, theoretical and empirical models;
- The delay in the South America is calculated by different data sources (empirical, ground and altitude stations, NWP models) zenithal, as well as the ray tracing technique to obtain the slant delay or mapping functions, is presented in Table 1.

Table 1– Neutral atmosphere delay modeling methodology, considering the different data sources and different models of the zenith and mapping functions.

Product	Features	Address
SIRGAS/ZTD GNSS	VMFs (elevation 3°) Time resolution: 60 min (24h/day) Spatial resolution: network SIRGAS	ftp://ftp.sirgas.org/pub/gps/SIRGAS-ZPD/
EMBRACE/ZTD/IWV GNSS	VMF (elevation 7°) Time resolution: 5min (24h/day) Spatial resolution: network RBMC	http://www2.inpe.br/climaespacial/portal/iwv/
Zenith delay CPTEC NWP/CPTEC/INPE	$d_h^z, d_{nh}^z, d_{wh}^z$ Time resolution: 1h (24h/day) Spatial resolution: grid South America	http://satelite.cptec.inpe.br/zenital/
Zenith delay automatic Blind Models (Hop, Saa, GPT/GMF, GPT2/VMF1, GPT3/VMF3	$d^z, d_h^z, d_{wh}^z, mf_h, mf_{wh}$ Time resolution: climatology Spatial resolution: Global	In development
Zenith delay automatic Ground(INMET)/Altitude (Un. Wyoming)	d^z, d_h^z, d_{wh}^z Time resolution: 6h or 12h (24h/day) Spatial resolution: Brazil	In development
BMF Raytracer+NWP/CPTEC/INPE	d_h , $d_{wh}, d_h^z, d_{wh}^z, mf_h, mf_{wh}$ Time resolution: 1h (24h/day) Spatial resolution: grid South America	In development

BRAZILIAN PRODUCTS

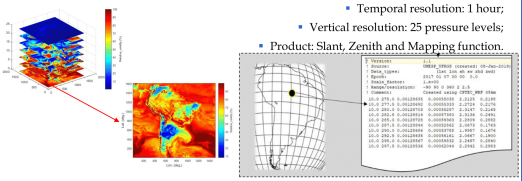
Figure 4 - Assessment of the Blind Models in the Brazil regions.



- The main impact on ZTD quality (c) is directly related to ZWD quality (b);
- The model with the worst performance was GTP2, in 78.6 of the cases, compared ZTD/Blind models with ZTD/GNSS;
- The GPT2w (85.7%) and GPT3 (57%) were showed the best performances.

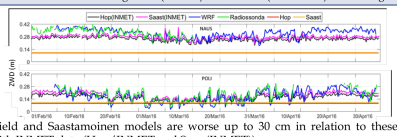
BRAZILIAN PRODUCTS

Figure 5 – Brazilian Mapping Function (BMF)



- Regional WRF NWM model – South America;
- Spatial resolution: 5km;
- Temporal resolution: 1 hour;
- Vertical resolution: 25 pressure levels;
- Product: Slant, Zenith and Mapping function.

Figure 6 – Assessment of ZTD from ground (INMET) and altitude (radiosonde) meteorological station



- The Hopfield and Saastamoinen models are worse up to 30 cm in relation to these models improved with INMET data (Hop/INMET and Saas (INMET));
- The BMF/WRF has the best performance in relation to the ZWD estimated with radiosondes (reference measurements).

CHALLENGES AND FINAL CONSIDERATIONS

- The climatic variation in Brazil has strong impact on the quality of the neutral atmospheric delay, mainly in no-hydrostatic delay (or wet);
- Global empirical models are not capable of expressing the real variability of the delay over a day or hours, but they can be applied in the absence of other models;
- Regional NWP models, such as those of CPTEC/INPE, have high horizontal, vertical and temporal resolutions and can be considered the best options for Brazil and South America;
- Better delay modeling in Brazilian regions, of the BMF and the ZTD/GNSS estimation, has being developed.

ACKNOWLEDGMENTS

unesp
CNPq
Fundunesp
CPTEC