Local Ionosphere Modeling Using GNSS Reference Stations Network in Morocco

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Outline

- Introduction
- Motivations
- Modeling Approach
- Assessment
- Activities related to space weather
Introduction

- GNSS contributed to advancing the understanding of the ionosphere in the last decades.
- At the same time GNSS techniques have benefited from improved knowledge of the electron content distribution in time and space.
- The increase knowledge has been made possible due to the use of GNSS with its unprecedented high temporal and spatial sampling rates.
- Implementation of new GNSS Infrastructure.
- Development of local products to support the use of GNSS PPP positioning.
Motivations

1. Scientific:

Accurate knowledge of ionosphere conditions can in turn be used to improve geodetic techniques:

- Evaluation and application of higher-order ionosphere corrections.
- High-precision GNSS real-time positioning.
Motivations

2. Operational:

Ionosphere modeling is critical for mass-market single frequency users and for many national priority applications:

- Surveying, mapping, construction
- Precision agriculture, land administration
- Weather forecasting models
- Automatic vehicle location and in-vehicle navigation systems
Motivations

3. Outreach:

Raise awareness of the usefulness of space weather science for the following reasons:

- Obtain the involvement of national organizations in research activities by showing the benefit through products that meet their needs.
- Create a service that has a societal impact.
- Have access to data and instruments of national administrations concerned.
- Collect national funds and logistical support for science and education activities related to Space Weather.
**GNSS Data in Morocco**

- Many agencies are deploying GNSS permanent stations
  - ANCFCC, CNRST, DMN, UNAVCOO, Universities.

- Currently only 01 IGS station located in Morocco

- More than 30 National GNSS Stations
Modeling Approach

1. Calculation of the ionosphere delay by linear combination: Geometry-free

2. Single layer model at h=350 km

3. Mapping with polynomial function

High spatial and temporal resolution are required:

15 - 20 min on a 0.5° X 0.5° grid

- Integration of all National GNSS Permanent Reference Stations (NPRS);
- Near real time availability
TEC determination

\[ P_{r,f_i} = \rho_r^s + c \ast dt_{rec} - c \ast dt^{sat} - c \ast \Delta t^{sat} + d_{f_i}^s + d_{r,f_i} + T_{r,f_i}^s + I_{r,f_i}^s \]

\[ + \Delta R_r^s + m_r^s + e_{P,r}^s \]

\[ L_{r,f_i}^s = \rho_r^s - \lambda \ast N_r^s + c \ast dt_{rec} + b_{r,f_i} - \lambda \ast \phi_r(t_0) - c \ast dt^{sat} - c \ast \Delta t^{sat} \]

\[ + b_{f_i}^s + \lambda \ast \phi^s(t_0) + T_{r,f_i}^s - I_{r,f_i}^s + \Delta R_r^s + \mu_r^s + dp_u^s + \varepsilon_{P,r}^s \]

\[ P_{r,f_1} - P_{r,f_2} = I_{r,f_1}^s - I_{r,f_2}^s + (d_{f_1}^s - d_{f_2}^s) + (d_{r,f_1} - d_{r,f_2}) \]

\[ P_1 - P_2 = 40.3 \left( \frac{1}{f_1^2} - \frac{1}{f_2^2} \right) \ast STEC + c \ast (DCB_r^s + DCB_r) \]
Polynomial model

\[
STE C = \frac{1}{CI} [P4 + c \cdot (D CB^s + D CB_r)] \\
V T E C = S T E C \cdot \sqrt{1 - \left(\frac{R}{R + H \cos \beta}\right)^2}
\]

\[
V T E C = \frac{1}{CI} [(P1 - P2) + c \cdot (D CB^s + D CB_r)] \cdot \sqrt{1 - \left(\frac{R}{R + H \cos \beta}\right)^2}
\]

\[
V T E C (\beta, s) = \sum_{n=0}^{n_{\text{max}}} \sum_{m=0}^{m_{\text{max}}} E_{nm} (\beta - \beta_0)^n (s - s_0)^m
\]
Program Rinex-TEC (Rolland Fleury)
Assessment
Comparison LIM & GIM

Rbat - 2001

RMSE_GIM = 10 Tcu ; RMSE_LIM = 4 Tcu

MAX_DIFF = 17 Tcu ; STD_DIFF = 5 Tcu
Comparison LIM & GIM

Rbat - 2009

RMSE_GIM = 10 Tecu ; RMSE_LIM = 4 Tecu

MAX_DIFF = 17 Tecu ; STD_DIFF = 5 Tecu
Comparison LIM & GIM
Rbat - 2013

RMSE_GIM = 10 Tecu ; RMSE_LIM = 4 Tecu
MAX_DIFF = 17 Tecu ; STD_DIFF = 5 Tecu

NO DATA
Impact on positioning

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TEC Mapping

Iono-Pierce Points

VTEC-Map

01/01/2014 à 12 H UT
Conclusion

- Involvement of public administrations in research activities
- Recent Applications: Mapping, Land delimitation, Forestry, Urban Navigation
- Integration of more GNSS Stations to obtain a dense network
- More improvements needed for LIM & Inclusion of more National Permanent Reference Stations
- Experimentations assessment for the integration in Real Time are ongoing
Training on Space weather-GNSS (Craste-LF, Rabat)

- 02/2015
- 01/2017
- 05/2017
Following a scientific collaboration agreement between scientific teams of Telecom Bretagne and the Geodesy department of IAV Hassan 2, a GNSS receiver for ionospheric scintillation monitoring was installed in Rabat, May 2017.

The exploitation and analysis of the data will be done within the framework of a PhD thesis which will be supervised jointly by the two partners.
Thank you