Effects of different estimation techniques of GPS-TEC on the validation of TEC models - comparison with values from IRI-2016, NeQuick-2 and IRI-Plas 2015 models

Dr Adekola O. Adewale
Department of Physics
University of Lagos, Nigeria
aadewale@unilag.edu.ng
Introduction

• TEC is an essential element for effective satellite communication and navigation.
• It constitutes one of the critical parameters for observing the variable structure of the ionosphere.
• Characterization of TEC plays a key role in space physics and space weather.
• Several applications rely on these estimated values – space weather studies, navigation, communication and validation with TEC models.
• Different estimation techniques.
Introduction

• Arikan et al. (2003) - three categories: computation of TEC using the pseudoranges, carrier phase delays, or a combination of pseudorange and phase delay measurements.

• The primary source of error - effect of the differential satellite and receiver instrumental delay biases.

• GPS-VTEC - IONOLAB group (Arikan et al., 2003) compared with Seemala (2011).

• Estimated VTECs compared with model predictions.


• The success of validation is a function of the reliability of the experimental values.
Data and Methodology

- Table 1: List of station names, their codes, and geographic coordinates

<table>
<thead>
<tr>
<th>Code</th>
<th>Station Name</th>
<th>Longitude</th>
<th>Latitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>ade1</td>
<td>Salisbury</td>
<td>138.6473</td>
<td>-34.729</td>
</tr>
<tr>
<td>Artu</td>
<td>Arti</td>
<td>58.5605</td>
<td>56.4298</td>
</tr>
<tr>
<td>azu1</td>
<td>Azusa</td>
<td>242.1</td>
<td>34.13</td>
</tr>
<tr>
<td>bay2</td>
<td>Cold Bay 2</td>
<td>197.2</td>
<td>55.1904</td>
</tr>
</tbody>
</table>

- for 5th – 9th April 2000
Data and Methodology

• The root-mean-square error (RMSE) has been used here to quantify the performance of the models.

\[ \text{RMSE} = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (\text{VTEC}_{\text{OBS}} - \text{VTEC}_{\text{IRI}})^2} \]

\[ \text{RMSE}_{\text{average}} = \frac{1}{k} \sum_{j=1}^{k} (\text{RMSE})_j \]
Plots of GOPI-VTEC, IONO-VTEC, IRI-2016 (IRI2001, IRI01cor, and IRI-NeQuick), IRI-Plas 2015 and NeQuick-2 for bay2
Results

Plots of GOPI-VTEC, IONO-VTEC, IRI-2016 (IRI2001, IRI01cor, and IRI-NeQuick), IRI-Plas 2015 and NeQuick-2 for ade1
Results

Plots of GOPI-VTEC, IONO-VTEC, IRI-2016 (IRI2001, IRI01cor, and IRI-NeQuick), IRI-Plas 2015 and NeQuick-2 for artu
Results

Plots of GOPI-VTEC, IONO-VTEC, IRI-2016 (IRI2001, IRI01cor, and IRI-NeQuick), IRI-Plas 2015 and NeQuick-2 for azu1
Results

Comparison between observed ionospheric foF2 and IRI-2001 predictions over periods of severe geomagnetic activities at Grahamstown, South Africa.
<table>
<thead>
<tr>
<th>Date</th>
<th>StationID</th>
<th>Gopi NeQ</th>
<th>Gopi IRI</th>
<th>Gopi NeQ IRI</th>
<th>Gopi IRI_2001</th>
<th>Gopi IRI01 Cor</th>
</tr>
</thead>
<tbody>
<tr>
<td>05-04-05</td>
<td>bay2</td>
<td>15.6</td>
<td>11.2</td>
<td>11.6</td>
<td>6.7</td>
<td>8.6</td>
</tr>
<tr>
<td>06-04-06</td>
<td>bay2</td>
<td>15.1</td>
<td>10.3</td>
<td>11.9</td>
<td>6.2</td>
<td>8.9</td>
</tr>
<tr>
<td>07-04-07</td>
<td>bay2</td>
<td>14.7</td>
<td>11.2</td>
<td>9.1</td>
<td>6.3</td>
<td>8.7</td>
</tr>
<tr>
<td>08-04-08</td>
<td>bay2</td>
<td>9.5</td>
<td>17.4</td>
<td>17.6</td>
<td>12.2</td>
<td>9.7</td>
</tr>
<tr>
<td>09-04-09</td>
<td>bay2</td>
<td>12.2</td>
<td>13.3</td>
<td>12.5</td>
<td>7.1</td>
<td>5.4</td>
</tr>
<tr>
<td>05-04-05</td>
<td>ade1</td>
<td>6.0</td>
<td>9.2</td>
<td>22.0</td>
<td>5.9</td>
<td>8.4</td>
</tr>
<tr>
<td>06-04-06</td>
<td>ade1</td>
<td>9.5</td>
<td>9.1</td>
<td>22.2</td>
<td>5.2</td>
<td>6.3</td>
</tr>
<tr>
<td>07-04-07</td>
<td>ade1</td>
<td>11.7</td>
<td>13.2</td>
<td>18.4</td>
<td>7.1</td>
<td>5.8</td>
</tr>
<tr>
<td>08-04-08</td>
<td>ade1</td>
<td>9.0</td>
<td>10.9</td>
<td>23.3</td>
<td>7.5</td>
<td>8.1</td>
</tr>
<tr>
<td>09-04-09</td>
<td>ade1</td>
<td>11.4</td>
<td>12.8</td>
<td>18.8</td>
<td>7.0</td>
<td>6.0</td>
</tr>
<tr>
<td>05-04-05</td>
<td>artu</td>
<td>18.3</td>
<td>6.5</td>
<td>16.0</td>
<td>6.6</td>
<td>6.5</td>
</tr>
<tr>
<td>06-04-06</td>
<td>artu</td>
<td>12.4</td>
<td>5.8</td>
<td>17.3</td>
<td>6.1</td>
<td>5.8</td>
</tr>
<tr>
<td>07-04-07</td>
<td>artu</td>
<td>9.3</td>
<td>5.6</td>
<td>12.8</td>
<td>8.7</td>
<td>7.8</td>
</tr>
<tr>
<td>08-04-08</td>
<td>artu</td>
<td>18.7</td>
<td>9.4</td>
<td>21.9</td>
<td>8.2</td>
<td>9.0</td>
</tr>
<tr>
<td>09-04-09</td>
<td>artu</td>
<td>12.7</td>
<td>5.7</td>
<td>16.0</td>
<td>7.3</td>
<td>7.1</td>
</tr>
<tr>
<td>05-04-05</td>
<td>azu1</td>
<td>9.7</td>
<td>22.1</td>
<td>16.4</td>
<td>8.4</td>
<td>10.0</td>
</tr>
<tr>
<td>06-04-06</td>
<td>azu1</td>
<td>9.2</td>
<td>18.6</td>
<td>15.7</td>
<td>8.6</td>
<td>9.0</td>
</tr>
<tr>
<td>07-04-07</td>
<td>azu1</td>
<td>8.7</td>
<td>22.6</td>
<td>16.1</td>
<td>6.1</td>
<td>9.3</td>
</tr>
<tr>
<td>08-04-08</td>
<td>azu1</td>
<td>7.9</td>
<td>21.6</td>
<td>14.3</td>
<td>10.5</td>
<td>8.8</td>
</tr>
<tr>
<td>09-04-09</td>
<td>azu1</td>
<td>9.2</td>
<td>22.8</td>
<td>16.4</td>
<td>6.7</td>
<td>8.8</td>
</tr>
<tr>
<td>Average rmse</td>
<td></td>
<td>15.6</td>
<td>13.0</td>
<td>16.6</td>
<td>7.6</td>
<td>7.5</td>
</tr>
</tbody>
</table>
## Results

### Average RMSE for IONO-VTEC

<table>
<thead>
<tr>
<th>Date</th>
<th>StationID</th>
<th>Iono_NeQ</th>
<th>Iono_IRI_Plas</th>
<th>Iono_NeQ_IRI</th>
<th>Iono_IRI_2001</th>
<th>Iono_IRI01_Cor</th>
</tr>
</thead>
<tbody>
<tr>
<td>05-05</td>
<td>bay2</td>
<td>17.5</td>
<td>15.6</td>
<td>13.2</td>
<td>14.5</td>
<td>13.4</td>
</tr>
<tr>
<td>06-05</td>
<td>bay2</td>
<td>17.0</td>
<td>14.1</td>
<td>11.1</td>
<td>12.9</td>
<td>10.9</td>
</tr>
<tr>
<td>07-05</td>
<td>bay2</td>
<td>16.9</td>
<td>15.1</td>
<td>10.6</td>
<td>13.7</td>
<td>11.4</td>
</tr>
<tr>
<td>08-05</td>
<td>bay2</td>
<td>9.4</td>
<td>12.3</td>
<td>11.6</td>
<td>5.1</td>
<td>4.3</td>
</tr>
<tr>
<td>09-05</td>
<td>bay2</td>
<td>12.8</td>
<td>12.8</td>
<td>9.2</td>
<td>9.1</td>
<td>6.7</td>
</tr>
<tr>
<td>05-06</td>
<td>ade1</td>
<td>5.8</td>
<td>10.4</td>
<td>18.7</td>
<td>7.7</td>
<td>8.1</td>
</tr>
<tr>
<td>06-06</td>
<td>ade1</td>
<td>15.4</td>
<td>11.4</td>
<td>17.9</td>
<td>10.3</td>
<td>8.6</td>
</tr>
<tr>
<td>07-06</td>
<td>ade1</td>
<td>17.0</td>
<td>15.6</td>
<td>14.6</td>
<td>14.7</td>
<td>13.1</td>
</tr>
<tr>
<td>08-06</td>
<td>ade1</td>
<td>11.7</td>
<td>11.5</td>
<td>19.0</td>
<td>9.8</td>
<td>7.4</td>
</tr>
<tr>
<td>09-06</td>
<td>ade1</td>
<td>16.3</td>
<td>15.0</td>
<td>14.7</td>
<td>13.8</td>
<td>12.1</td>
</tr>
<tr>
<td>05-07</td>
<td>artu</td>
<td>7.1</td>
<td>8.4</td>
<td>10.6</td>
<td>9.7</td>
<td>10.7</td>
</tr>
<tr>
<td>06-07</td>
<td>artu</td>
<td>4.5</td>
<td>7.9</td>
<td>11.9</td>
<td>10.2</td>
<td>9.8</td>
</tr>
<tr>
<td>07-07</td>
<td>artu</td>
<td>6.0</td>
<td>11.7</td>
<td>8.1</td>
<td>14.5</td>
<td>14.1</td>
</tr>
<tr>
<td>08-07</td>
<td>artu</td>
<td>6.4</td>
<td>4.4</td>
<td>16.0</td>
<td>6.9</td>
<td>6.4</td>
</tr>
<tr>
<td>09-07</td>
<td>artu</td>
<td>3.9</td>
<td>8.6</td>
<td>10.5</td>
<td>11.5</td>
<td>11.1</td>
</tr>
<tr>
<td>05-08</td>
<td>avul</td>
<td>12.3</td>
<td>28.5</td>
<td>20.9</td>
<td>8.2</td>
<td>15.2</td>
</tr>
<tr>
<td>06-08</td>
<td>avul</td>
<td>15.4</td>
<td>24.1</td>
<td>19.4</td>
<td>7.9</td>
<td>12.4</td>
</tr>
<tr>
<td>07-08</td>
<td>avul</td>
<td>18.4</td>
<td>30.3</td>
<td>21.5</td>
<td>12.3</td>
<td>16.0</td>
</tr>
<tr>
<td>08-08</td>
<td>avul</td>
<td>13.2</td>
<td>26.2</td>
<td>17.0</td>
<td>7.1</td>
<td>11.2</td>
</tr>
<tr>
<td>09-08</td>
<td>avul</td>
<td>18.2</td>
<td>30.2</td>
<td>21.4</td>
<td>11.9</td>
<td>15.8</td>
</tr>
</tbody>
</table>

**Average rms**: 12.2

---

9/20/2019 10:39:42 AM

9/20/2019 10:39:42 AM

Beacon Satellite Symposium 2019, University of Warmia and Mazury, Olsztyn; 19-23 August 2019
Conclusions

• Our results show the disparity in the estimated values of VTEC for the same days.

• The implication of this is that different VTEC model exhibit different performance levels when compared with the estimation techniques.

• The result shows that IRI-2001 has the best prediction for both estimation methods.

• This is in contrast with the work of Akala et al. (2015). They reported that, of the three options of IRI-2012 model, NeQuick appears to be the most accurate for TEC estimation over Addis Ababa, although at a very close performance capability with the IRI01 CORR option, while IRI2001 is the least reliable.

• The estimation technique for the observed VTEC likely played a significant role in this disparity.
THANK YOU

Dziękuję Ci