An Assessment and Comparison of WAAS Ionospheric Correction Algorithms in CONUS and Europe

Attila Komjathy, Lawrence Sparks and Anthony J. Mannucci

Jet Propulsion Laboratory
California Institute of Technology
M/S 238-600
4800 Oak Grove Drive
Pasadena CA 91109
Email: Attila.Komjathy@jpl.nasa.gov
From the WAAS performance point of view:

- Is the ionosphere any different over Europe compared to middle latitude CONUS?

- Would major storms have the same impact over Europe and CONUS?

- Would a quadratic fit improve on WAAS ionospheric residuals in the CONUS or Europe?
Outline

- Review of currently used estimation algorithms for GIM and WAAS
- Data set used for quiet and storm days: 19 days
  - Ground-truth generated using JPL’s GIM software
  - 19 days coincide with the focus period CONUS storm detector is based on;
- Comparison of WAAS planar and quadratic ionospheric model residuals for
  - CONUS and Europe and
  - Quiet and storm days to provide measure of performance in reproducing slant TEC for the user
- Conclusions
- Acknowledgement
For single shell, our Global Ionospheric Mapping (GIM) technique is

\[ TEC = M(h, E) \sum C_i B_i(lat, lon) + b_r + b_s \]

where

- \( TEC \) is the slant TEC
- \( M(h, E) \) is the thin shell mapping function
- \( B_i(lat, lon) \) is the horizontal basis function (C^2, TRIN, etc);
- \( C_{1i} \) are the basis function coefficients
- \( b_r, b_s \) are the satellite and receiver instrumental biases
- \( a_0, a_1, a_2 \) are the planar fit parameters
- \( d_E, d_N \) distances from IGP to IPP
WAAS planar fit ionospheric model is

\[ TEC = M(h,E)[a_0 + a_1 d_E + a_2 d_N] \]

where

\[ a_0, a_1, a_2 \]

are the planar fit parameters,

\[ d_E, d_N \]

are the distances from the IGP to the IPP in the eastern and northern directions, respectively.

Pseudo-IGP approach:
IPP treated as if it were collocated with IGP

WAAS quadratic fit ionospheric model is

\[ TEC = M(h,E)[a_0 + a_1 d_E + a_2 d_N + a_3 d_E^2 + a_4 d_E d_N + a_5 d_N^2] \]

\[ a_3, a_4, a_5 \]

are the additional planar fit parameters describing quadratic and cross terms.
Description of Dataset

Reference:
M. Bakry El-Arini

<table>
<thead>
<tr>
<th>Ionosphere Type</th>
<th>Ap Index</th>
<th>Kp Index</th>
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<tr>
<td>Quiet Ionosphere</td>
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<tr>
<td>Minor Storm</td>
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<tr>
<td>Major Storm</td>
<td>50</td>
<td>5.3</td>
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<tr>
<td>Severe Storm</td>
<td>Ap 100</td>
<td>Kp 6.7</td>
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Summary of Results

Examples 1 2 3 4

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1. CONUS and European Planar Fit Residuals for 000111

CONUS and Europe Analysis for 000111

- Europe RMS = 0.70 m
- CONUS RMS = 0.46 m

CONUS Analysis for 000111

- Planar Fit RMS = 0.46 m
- Quadratic Fit RMS = 0.45 m

Europe Analysis for 000111

- Planar Fit RMS = 0.70 m
- Quadratic Fit RMS = 0.59 m

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2. CONUS and European Planar Fit Residuals for 000405

CONUS and Europe Analysis for 000405
- Europe RMS = 1.13 m
- CONUS RMS = 0.58 m

CONUS and Europe Analysis for 000405
- Europe RMS = 1.13 m
- CONUS RMS = 0.58 m

CONUS Analysis for 000405
- Planar Fit RMS = 0.58 m
- Quadratic Fit RMS = 0.58 m

Europe Analysis for 000405
- Planar Fit RMS = 1.13 m
- Quadratic Fit RMS = 0.98 m

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3. CONUS and European Planar Fit Residuals for 000715

CONUS and Europe Analysis for 000715

- Europe RMS = 0.64 m
- CONUS RMS = 0.71 m

CONUS Analysis for 000715

- Planar Fit RMS = 0.71 m
- Quadratic Fit RMS = 0.63 m

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4. CONUS and European Planar Fit Residuals for 010331
Conclusions

- 15 out of 19 days show larger RMS of planar fit residuals in Europe than in CONUS.

- For large storms, such as on April 5, 2000 and March 31, 2001, Europe’s planar fit residuals are significantly larger than that of CONUS.

- July 15, 2000 storm seems to have impacted CONUS more than Europe.

- Overall planar fit residuals in Europe is 77 cm; in CONUS 56 cm: CONUS residuals are 27% percent smaller on average.

- A 10 percent RMS improvement is seen in Europe when using quadratic fit over planar fit.

- A 7 percent RMS improvement is seen in CONUS when using quadratic fit instead.
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