The cooperative IGS RT-GIMs: a reliable estimation of the global ionospheric electron content distribution in real time (summarized and updated)

Qi Liu, Manuel Hernández-Pajares, Heng Yang, Enric Monte-Moreno, David Roma-Dollase, Alberto García-Rigo, Zishen Li, Ningbo Wang, Denis Laurichesse, Alexis Blot, Qile Zhao, Qiang Zhang, André Hauschild, Loukis Agrotis, Martin Schmitz, Gerhard Wübbena, Andrea Stürze, Andrzej Krankowski, Stefan Schaer, Joachim Feltens, Attila Komjathy, and Reza Ghoddousi-Fard

UPC-IonSAT research group
IGS real-time working group
IGS Ionosphere working group
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Qilin Liu, Manuel Hernández-Pajares, Hongyang Yang, Eric Monte-Moreno, David Ronca-Dell’Agn, Alberto García-Ripoll, Zichao Li, Ningbo Wang, Daozhe Lühr, Aodong Zhao, Quan Zhang, Andre Haustein, Lodovic Argò, Martin Schmid, Gerhard Wild, Andrea Miiller, Andrzej Krzakowski, Stefan Sotzne, Joachim Fettweis, Alina Kenigzajt, and Rosa Ghedi

Department of Mathematics, Universitat Politècnica de Catalunya (UPC-IonSAT), Barcelona, Spain
Institut d’Estudis Espacials de Catalunya (IEEC), Barcelona, Spain
School of Electronic Information and Engineering, Yangtze Normal University, 461000 Chongqing, China
Department of Signal Theory and Communications, TULF, Universitat Politècnica de Catalunya, 08034 Barcelona, Spain
Aerospace Information Research Institute (AIR), Chinese Academy of Sciences (CAS), Beijing, China
Center for International Studies, Tulane University, New Orleans, LA 70118, USA
Carrington Technology, Wuhan University, No. 120 Luoyu Road, Wuhan 430072, China
Collaborative Innovation Center of Earth and Space Science, Wuhan University, No. 120 Luoyu Road, Wuhan 430072, China
German Aerospace Center (DLR), German Space Operations Center (GSOC), 82234 Wessling, Germany
European Space Operations Center, European Space Agency, Darmstadt, Germany
Geos-1 GmbH, Steinenweg 6, 58271 Gelsenkirchen, Germany
HBKU, Federal Agency for Cartography and Geodesy, Bad Nauheim, Germany
Space Radio Diagnostics Research Center, University of Warsaw and Murray in Ouarzazate, 10719 Ouarzazate, Poland
Astronomical Institute, the University of Bern, Sidobre 5, Bern 3032, Switzerland
Federal Office of Topography (swisstopo), Wabern, Switzerland
Nominatex Support Office, Telekommunikations-GmbH DW European Space Agency/European Space Operations Centre, Robert Bosch-Strasse 5, 66293 Darmstadt, Germany
Near Earth Tracking Systems Group (NET), NASA Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, MS 138-317, Pasadena, CA 91109, USA
Canadian Geodetic Survey, Natural Resources Canada, Ottawa, Canada
Correspondence: Manuel Hernandez-Pajares (manuel.hernandez@upc.edu)

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Abstract. The Real-Time Working Group (RTWG) of the International GNSS Service (IGS) is dedicated to providing high-quality data and high-accuracy products for Global Navigation Satellite Systems (GNSS) positioning, navigation, timing and Earth observations. As one part of real-time products, the IGS combined Real-Time Global Ionosphere Map (RT-GIM) has been generated by the dual-time weighting of the RT-GIMs from IGS real-time ionosphere centers including the Chinese Academy of Sciences (CAS), Center National d’Études Spatiales (CNES), Universitat Politècnica de Catalunya (UPC) and Wuhan University (WHU). The performance of global vertical total electron content (VTEC) representation in all of the RT-GIMs has been assessed by VTEC from Jason-3 altimeter for 3 months over oceans and IONSAT-GPS technique with 24 observations over
IGS real-time combined GIM

- GNSS real-time data
- RT-GIMs of different centers
- IGS real-time ionosphere combination center
- IGS real-time combined GIM (IRTG)
- HTTP
- NTRIP Caster

CAS, CNES, UPC, WHU
# The broadcasting of IGS RT-GIMs

<table>
<thead>
<tr>
<th>Agency</th>
<th>Temporal resolution</th>
<th>Broadcast frequency</th>
<th>Spherical harmonic degree</th>
<th>Mountpoints in NTRIP caster (in SSR format)</th>
<th>Real-Time IONEX files saved at FTP/HTTP</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAS</td>
<td>5 minutes</td>
<td>1 minute</td>
<td>15</td>
<td>59.110.42.14:2101/SSRA00CAS1 59.110.42.14:2101/SSRA00CAS0 59.110.42.14:2101/SSRC00CAS1 59.110.42.14:2101/SSRC00CAS0 182.92.166.182:2101/IONO00CAS1 182.92.166.182:2101/IONO00CAS0</td>
<td>ftp://ftp.gipp.org.cn/product/ionex/ (update at the end of day)</td>
</tr>
<tr>
<td>CNES</td>
<td>2 minutes</td>
<td>1 minute</td>
<td>12</td>
<td>products.igs-ip.net:2101/SSRA00CNE1 products.igs-ip.net:2101/SSRA00CNE0 products.igs-ip.net:2101/SSRC00CNE1 products.igs-ip.net:2101/SSRC00CNE0</td>
<td>No</td>
</tr>
<tr>
<td>UPC-IonSAT</td>
<td>15 minutes</td>
<td>15 seconds</td>
<td>15</td>
<td>products.igs-ip.net:2101/IONO00UPC1</td>
<td><a href="http://chapman.upc.es/tomi.on/real-time/quick/">http://chapman.upc.es/tomi.on/real-time/quick/</a> (update every 15 min)</td>
</tr>
<tr>
<td>WHU</td>
<td>5 minutes</td>
<td>1 minute</td>
<td>15</td>
<td>58.49.58.150:2106/IONO00WHU0</td>
<td>ftp://igs.gnsswhu.cn/pub/w hu/MGEX/realtime-ionex/ (update every 30 min)</td>
</tr>
<tr>
<td>IRTG (IGS)</td>
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<td>15 seconds</td>
<td>15</td>
<td>products.igs-ip.net:2101/IONO00IGS1</td>
<td><a href="http://chapman.upc.es/irtg/">http://chapman.upc.es/irtg/</a> (update every 20 min)</td>
</tr>
</tbody>
</table>
Jason3 VTEC assessment around the beginning of 2021
Jason3 VTEC assessment from 2021 to 2022
### Statistics of Jason3 VTEC assessment

Overall standard deviation of the GIM-VTEC versus measured Jason-3 VTEC in Jason3 VTEC assessment (TECU)

<table>
<thead>
<tr>
<th>GIM</th>
<th>From 1 December 2020 to 3 January 2021</th>
<th>From 4 January to 1 March 2021</th>
<th>From 4 January 2021 to 1 June 2022</th>
<th>From 4 January 2022 to 1 June 2022</th>
</tr>
</thead>
<tbody>
<tr>
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<td>2.9</td>
<td>3.8</td>
<td>4.9</td>
</tr>
<tr>
<td>ehrG</td>
<td>3.0</td>
<td>2.8</td>
<td>3.6</td>
<td>4.5</td>
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<tr>
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<td>2.9</td>
<td>3.9</td>
<td>5.1</td>
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<td>4.9</td>
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<tr>
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<td>2.8</td>
<td>3.3</td>
<td>4.0</td>
</tr>
<tr>
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<td>2.7</td>
<td>3.4</td>
<td>4.2</td>
</tr>
<tr>
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<td>2.8</td>
<td>3.1</td>
<td>3.6</td>
</tr>
<tr>
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<td>2.8</td>
<td>3.3</td>
<td>4.0</td>
</tr>
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<td>2.8</td>
<td>3.1</td>
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<tr>
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<td>2.5</td>
<td>3.2</td>
<td>4.0</td>
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<td>6.2</td>
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<td>2.7</td>
<td>3.4</td>
<td>4.2</td>
</tr>
<tr>
<td>whu0</td>
<td>4.3</td>
<td>4.4</td>
<td>5.0</td>
<td>6.5</td>
</tr>
<tr>
<td>irTG</td>
<td>3.3</td>
<td>2.8</td>
<td>3.5</td>
<td>4.5</td>
</tr>
</tbody>
</table>
Recent activities & Potential new applications

- Recent activities

  CAS has started to provide a second real-time GIM combination: IONO01IGS0 / IONO01IGS1
  The quality monitoring of IGS real-time GIMs are available on IGS RTS website

- Potential space weather applications

  **Space Weather**
  RESEARCH ARTICLE
  10.1029/2021SW002853

  **Ionospheric Storm Scale Index Based on High Time Resolution UPC-IonSAT Global Ionospheric Maps (IsUG)**
  Qi Liu1, Manuel Hernández-Pajares1,2, Haixia Lyu3,4, Michi Nishioka4, Heng Yang4,5, Enric Monte-Moreno6,7, Tamara Gulyaeva7, Yannick Béniguel8, Volker Wilken9, Germán Olivares-Pulido10, and Raúl Orús-Pérez10

  **Space Weather**
  RESEARCH ARTICLE
  10.1029/2021SW002926

  **A New Way of Estimating the Spatial and Temporal Components of the Vertical Total Electron Content Gradient Based on UPC-IonSAT Global Ionosphere Maps**
  Qi Liu1, Manuel Hernández-Pajares1,2, Heng Yang1,3, Enric Monte-Moreno4, Alberto García-Rigo1,2, Haixia Lyu1,5, Germán Olivares-Pulido1, and Raúl Orús-Pérez6

Details have been presented at Iono. WG session 27 June 2022
Thanks for you attention!
Back-up Slides
The current phase of solar cycle

Figure from Space Weather Prediction Center
https://www.swpc.noaa.gov/products/solar-cycle-progression
Broadcasting and receiving SH expansions in SSR format

\[
M_z = \left[1 - \frac{\sin^2 z}{(1 + \frac{H_{\text{ion}}}{R_E})^2}\right]^{-\frac{1}{2}}
\]

\[
\text{VTEC}_t = \text{STEC}_t / M_z
\]

\[
\text{VTEC}_t = \sum_{n=0}^{N_{\text{SH}}} \sum_{m=0}^{\min(n, M_{\text{SH}})} P_{n,m}(\sin \varphi_I) \cdot (C_{n,m} \cos(m \lambda_{S,t}) + S_{n,m} \sin(m \lambda_{S,t}))
\]

\[
\lambda_{S,t} = (\lambda_I + (t - t_0) \times \pi / 43 200) \mod 2\pi
\]
GIM assessment methods

Jason VTEC