

Ionosphere Working Group

Andrzej Krankowski



Overview of the IonoWG

Membership

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| 1. Mahdi Alizadeh (TU Berlin and K.N.Toosi University of Technology: Tehran) | 20. Richard B. Langley (UNB) |
| 2. Dieter Bilitza (GSFC/NASA), | 21. Reinhard Leitinger (TU Graz) |
| 3. Ljiljana R. Cander (RAL) | 22. Zishen Li (CAS) |
| 4. M. Codrescu (SEC) | 23. Maria Lorenzo (ESA/ESOC) |
| 5. Anthea Coster (MIT) | 24. Angelyn Moore (JPL) |
| 6. Patricia H. Doherty (BC) | 25. Raul Orus (UPC) |
| 7. John Dow (ESA/ESOC) | 26. Michiel Otten (ESA/ESOC) |
| 8. Joachim Feltens (ESA/ESOC) | 27. Ola Ovstedal (UMB) |
| 9. Mariusz Figurski (MUT) | 28. Ignacio Romero (ESA/ESOC) |
| 10. Pawel Flisek (UWM) | 29. Jaime Fernandez Sanchez (ESA/ESOC) |
| 11. Adam Froń (UWM) | 30. Stefan Schaer (CODE) |
| 12. Alberto Garcia-Rigo (UPC) | 31. Michael Schmidt (DGFI-TUM) |
| 13. Reza Ghoddousi-Fard (UNB) | 32. Javier Tegedor (ESA/ESOC) |
| 14. Manuel Hernandez-Pajares (UPC) | 33. Ningbo Wang (CAS) |
| 15. Pierre Heroux (NRCAN) | 34. Rene Warnant (ROB) |
| 16. Norbert Jakowski (DLR) | 35. Robert Weber (TU Wien) |
| 17. Attila Komjathy (JPL) | 36. Pawel Wielgosz (UWM) |
| 18. Andrzej Krankowski (UWM) | 37. Brian Wilson (JPL) |
| 19. Kacper Kotulak (UWM) | 38. Yunbin Yuan (CAS) |
| | 39. Qile Zhao (WHU) |
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Overview of the IonoWG

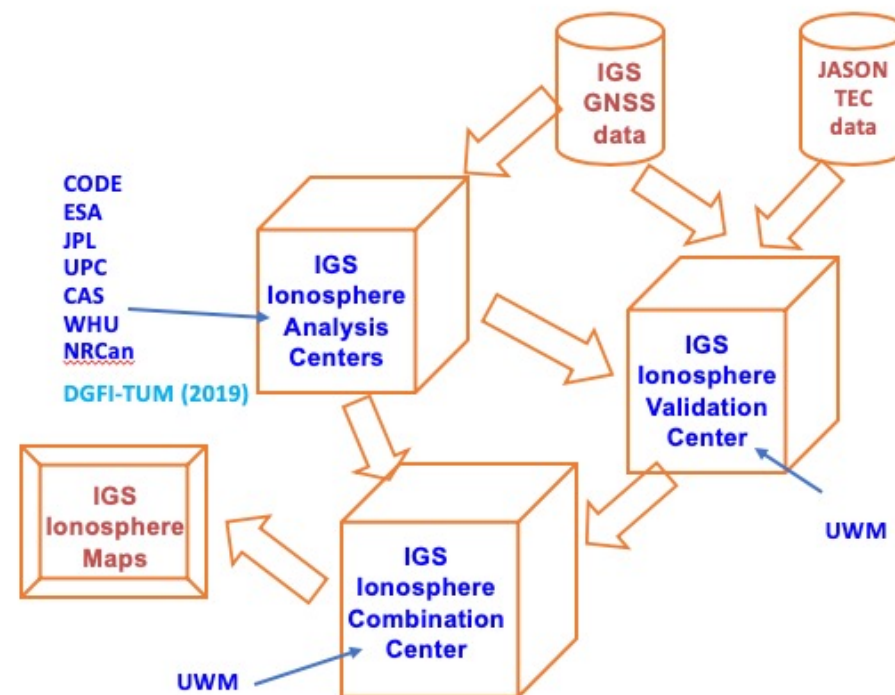
The IGS Ionosphere Working group started its activities in June 1998 with the main goal of a routinely producing IGS Global TEC maps.

This is being done now with a latency of 11 days (final product) and with a latency of less than 24 hours (rapid product).

This has been done under the direct responsibility of the Iono-WG chairmans:

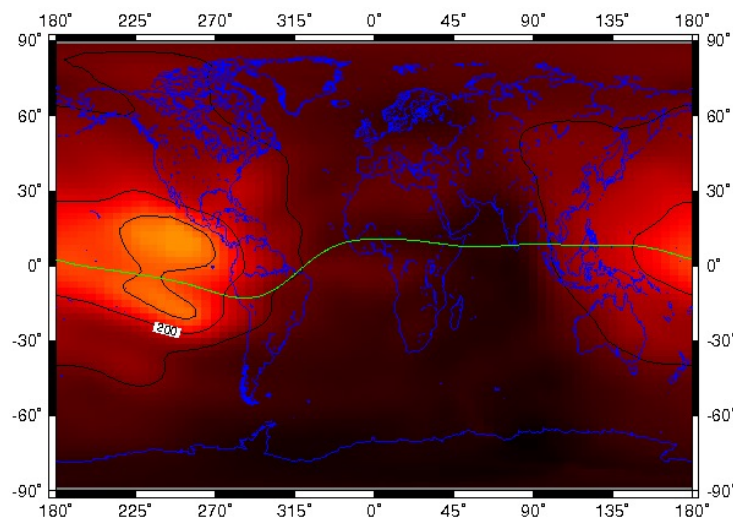
1. Dr Joachim Feltens, ESA 1998–2002,
2. Prof. Manuel Hernández-Pajares, UPC, 2002–2007
3. Prof. Andrzej Krankowski, UWM, 2008–

The IGS ionosphere product is a result of the combination of TEC maps derived by different Analysis Centers by using weights computed by Validation Center, in order to get a more accurate product.

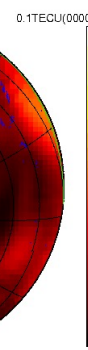
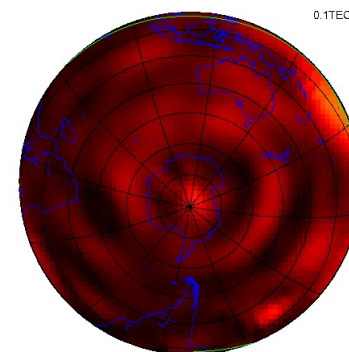
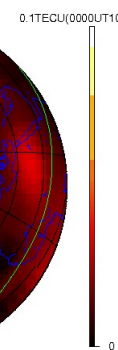
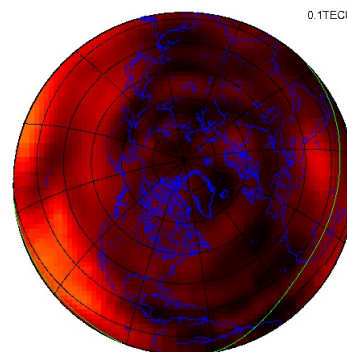
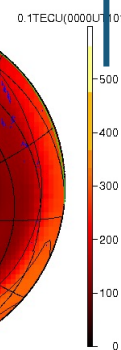
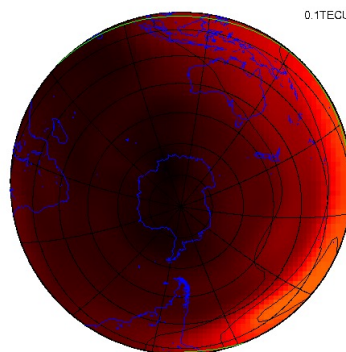
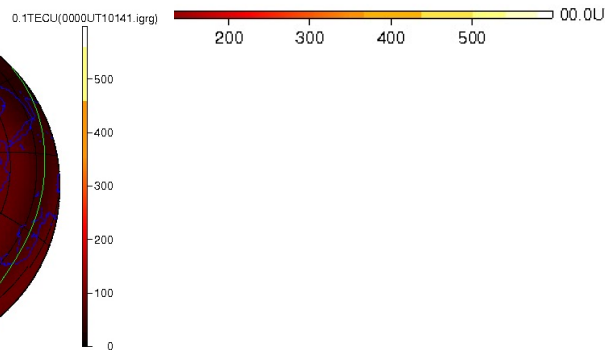
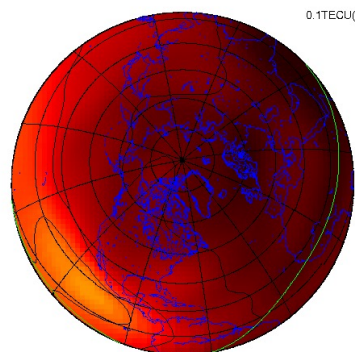
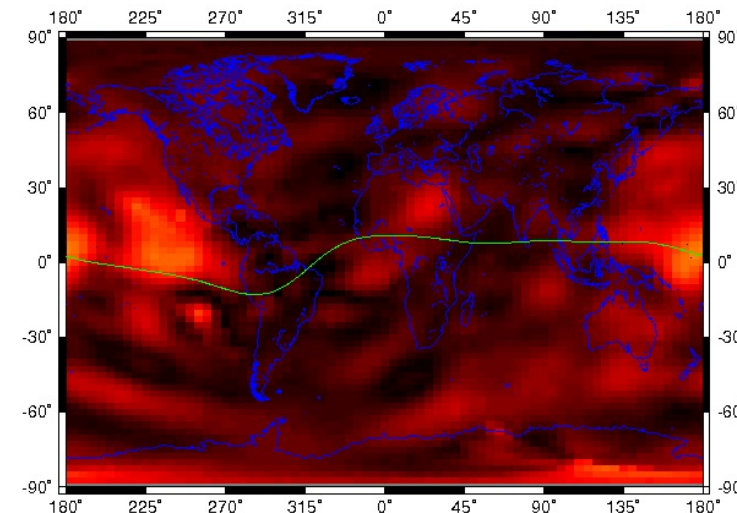


Example of IGS RAPID GIM: 2010-141 DOY

TEC maps

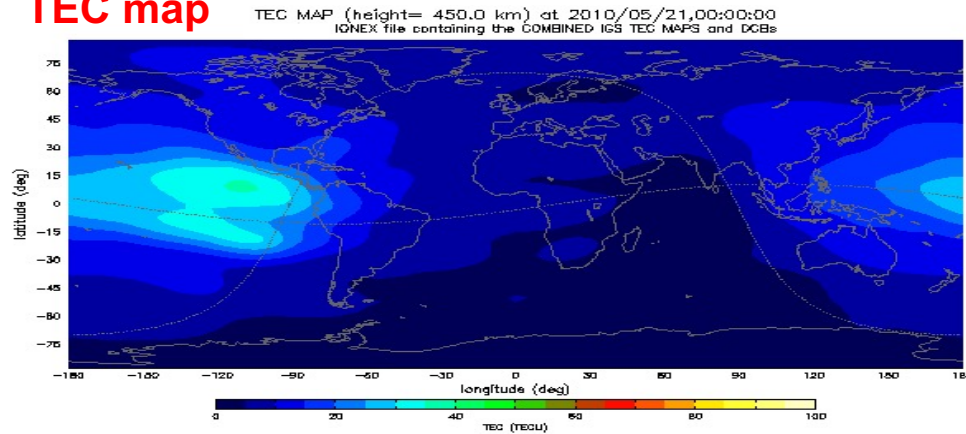


RMS maps

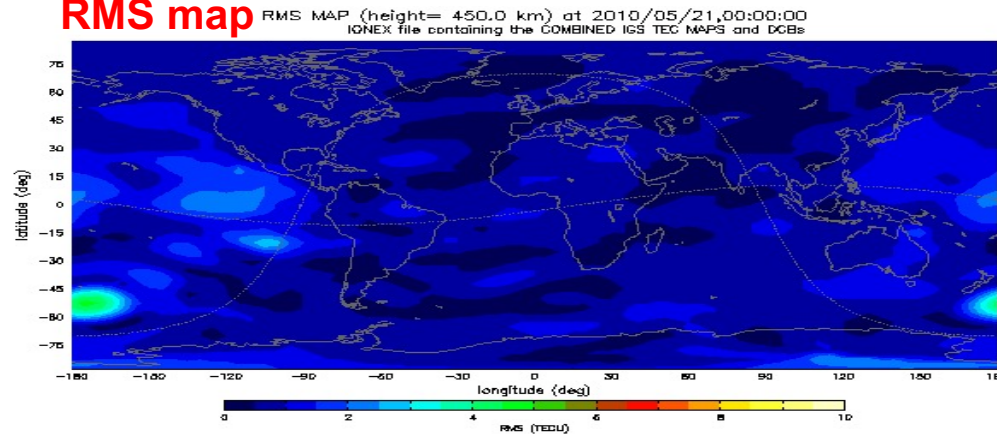


Example of IGS Final GIM: 2010-141 DOY

TEC map



RMS map

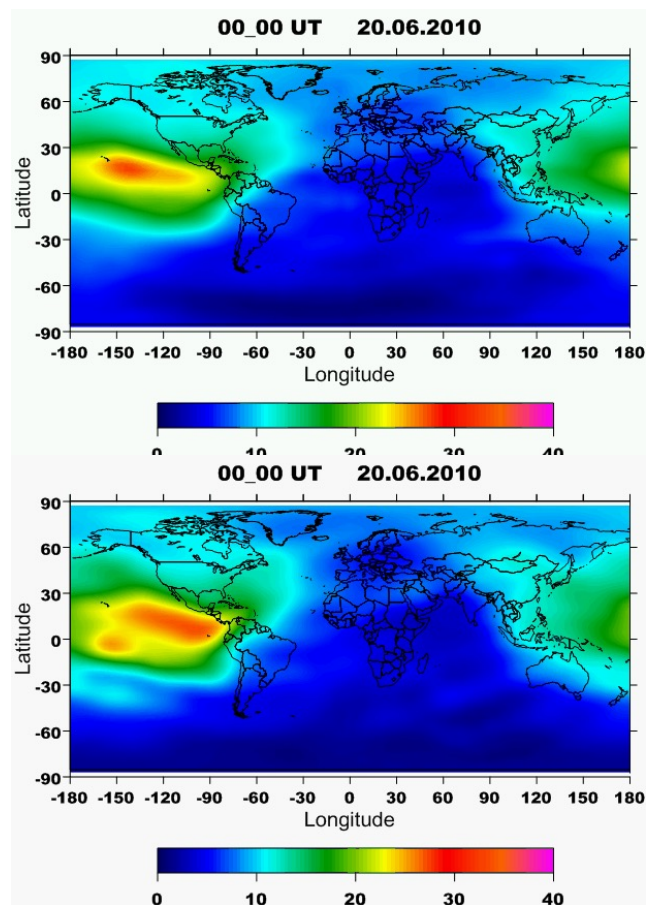


8 Analysis Centers: CODE, ESA, JPL, UPC, WHU, CAS, NRCan, DGFI-TUM (since 2019) and a Validation Center (UWM) have been providing maps (at 2 hours x 5 deg. x 2.5 deg in UT x Lon. x Lat.), weights and external (altimetry-derived) TEC data.

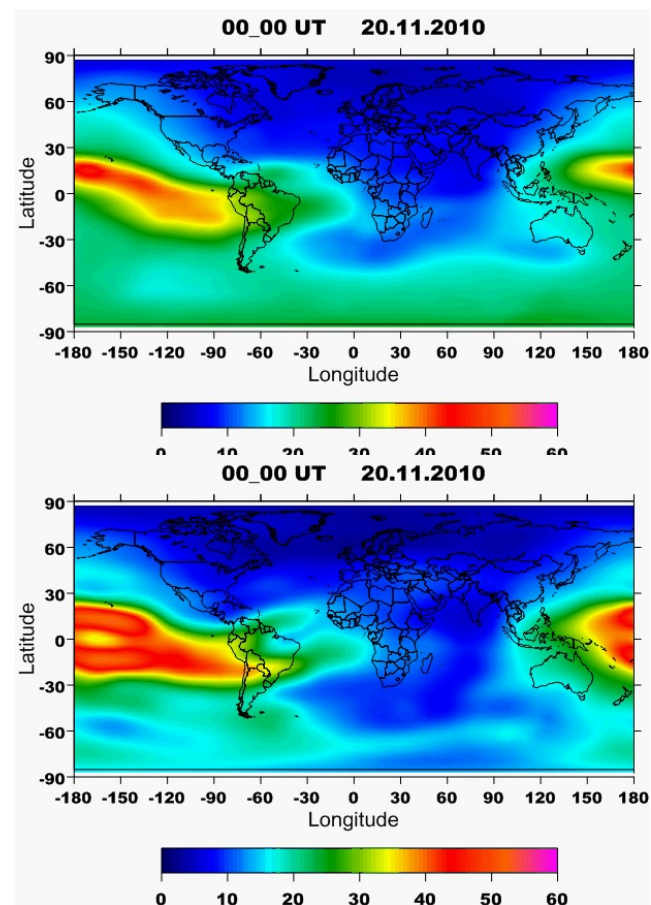
From such maps and weights the Combination Center (at first ESA, then UPC, and since 2008 - UWM) has produced the IGS TEC maps in IONEX format.

Example of IGS PREDICTED GIM

June 20, 2010



November 20, 2010



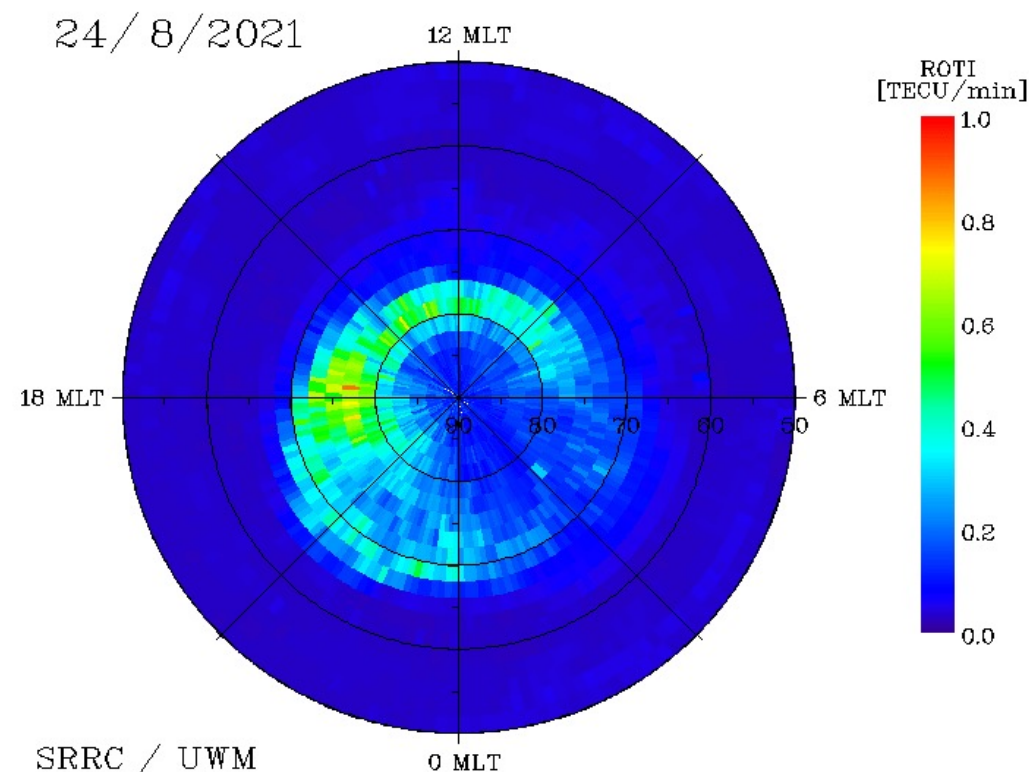
IGS Predicted GIM

IGS Final GIM

Example of IGS ROTI Maps Product

- The ROTI Maps processor operates routinely since January, 1, 2015
- It was processed and collected data and resulted product from 2010 up to now since the test service established
- ROTI Maps product available on NASA CDDIS
- Representative stations database have been actualised for 2020-2021 on base data availability and latency
- Finished reprocessing of ROTI Maps for 2020-2021 on base updated stations database

The activity has significant group of geophysical users interested in.



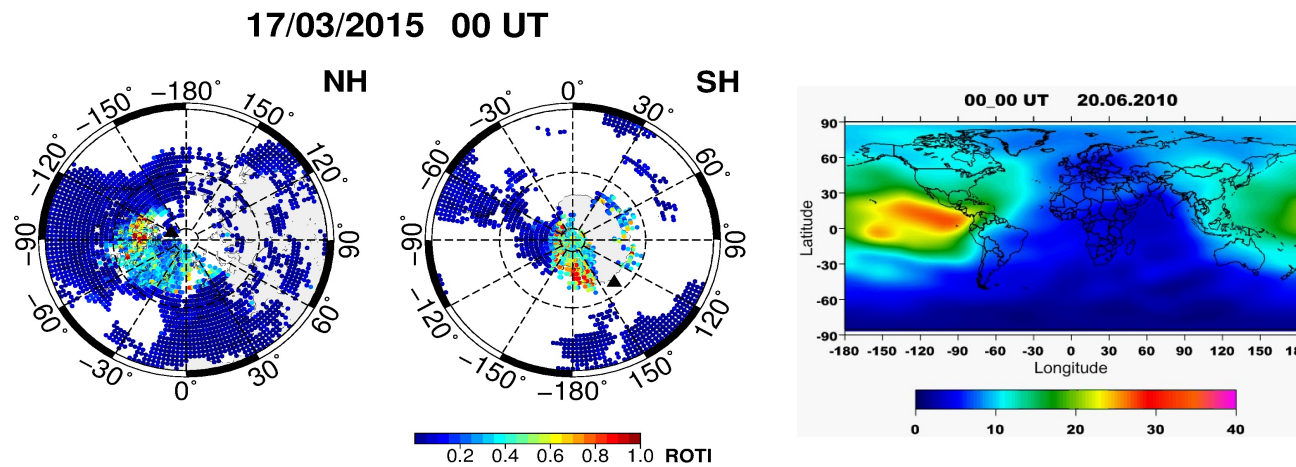
Ionospheric irregularities intensification and extension captured by IGS ROTI Maps. Moderate geomagnetic storm, August 2021

Progress since last AM Meeting (Dec 2019)

Recommendations

IGS 2018 Workshop 2018
 "Multi-GNSS through Global Collaboration"
 29 October – 2 November 2018
 Wuhan, China

- 1) To accept DGFI-TUM as new Ionospheric Analysis Center, contributing to the IGS combined VTEC GIMs.
- 2) To aim to additional real-time ionospheric analysis centers to join to the going-on experimental real-time IGS Global Ionospheric Maps combination.
- 3) To aim to additional ionospheric analysis centers to join to the going-on experimental IGS ionospheric ROTI fluctuations maps combination.
- 4) Cooperation with IRI COSPAR group for potential improvement of both IRI and IGS TEC.
- 5) Cooperation with International LOFAR Telescope (ILT) for potential synergies.



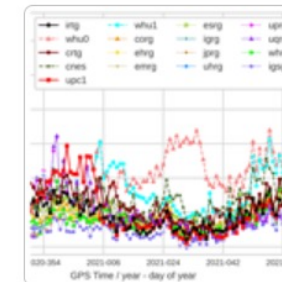
Looking for optimal ways to combine IGS global ionospheric maps in real-time

More details about IGS RT-GIM

Data description paper

23 Sep 2021

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



<https://essd.copernicus.org/articles/13/4567/2021/essd-13-4567-2021.html>

Qi Liu¹, Manuel Hernández-Pajares^{1,2}, Heng Yang^{3,1}, Enric Monte-Moreno⁴, David Roma-Dollase², Alberto García-Rigo^{1,2}, Zishen Li⁵, Ningbo Wang⁵, Denis Laurichesse⁶, Alexis Blot⁶, Qile Zhao^{7,8}, Qiang Zhang⁷, André Hauschild⁹, Loukis Agrotis¹⁰, Martin Schmitz¹¹, Gerhard Wübbena¹¹, Andrea Stürze¹², Andrzej Krankowski¹³, Stefan Schaer^{14,15}, Joachim Feltens¹⁶, Attila Komjathy¹⁷, and Reza Ghoddousi-Fard¹⁸

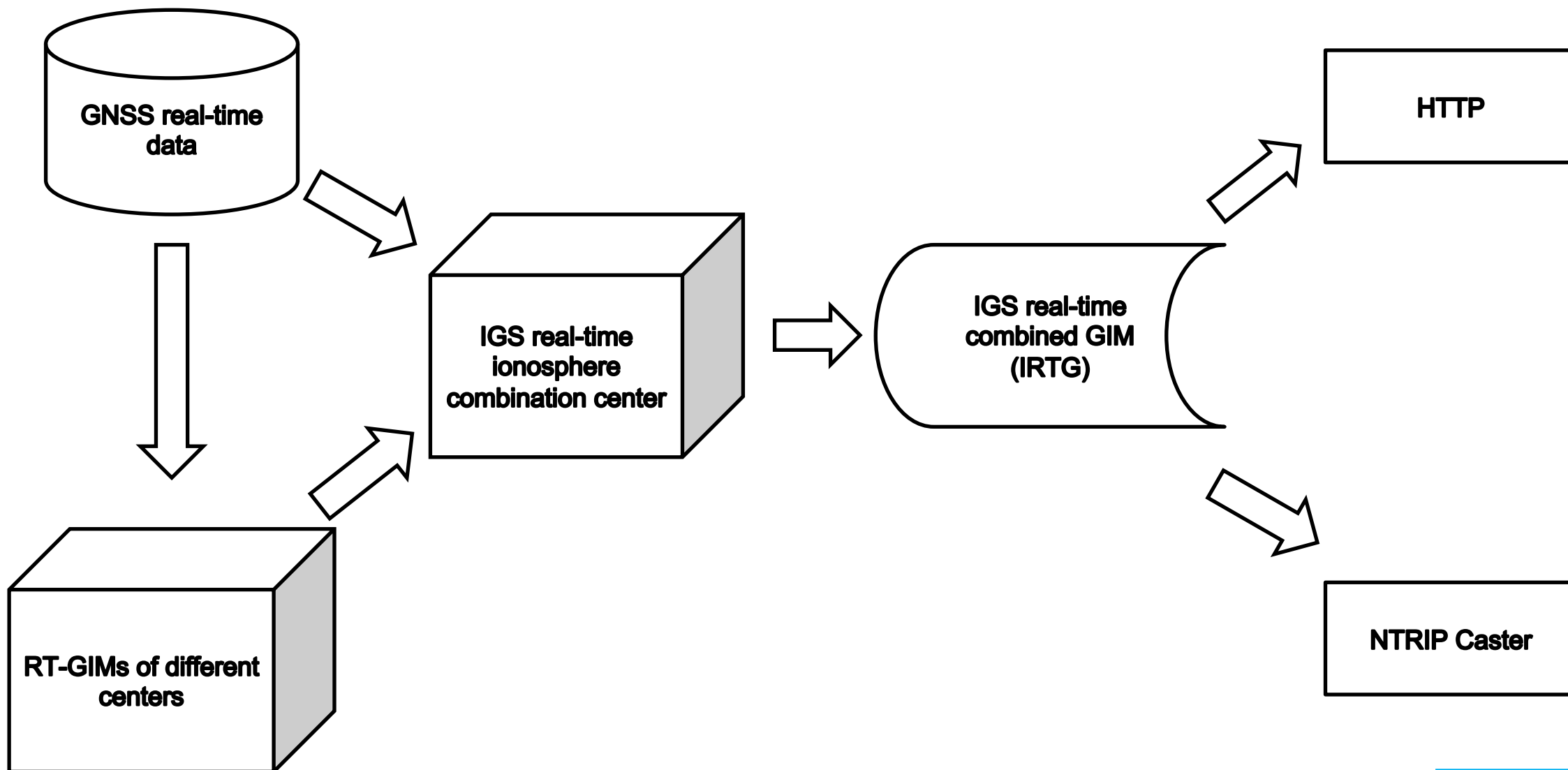
Original Article | [Published: 18 February 2020](#)

IGS real-time service for global ionospheric total electron content modeling

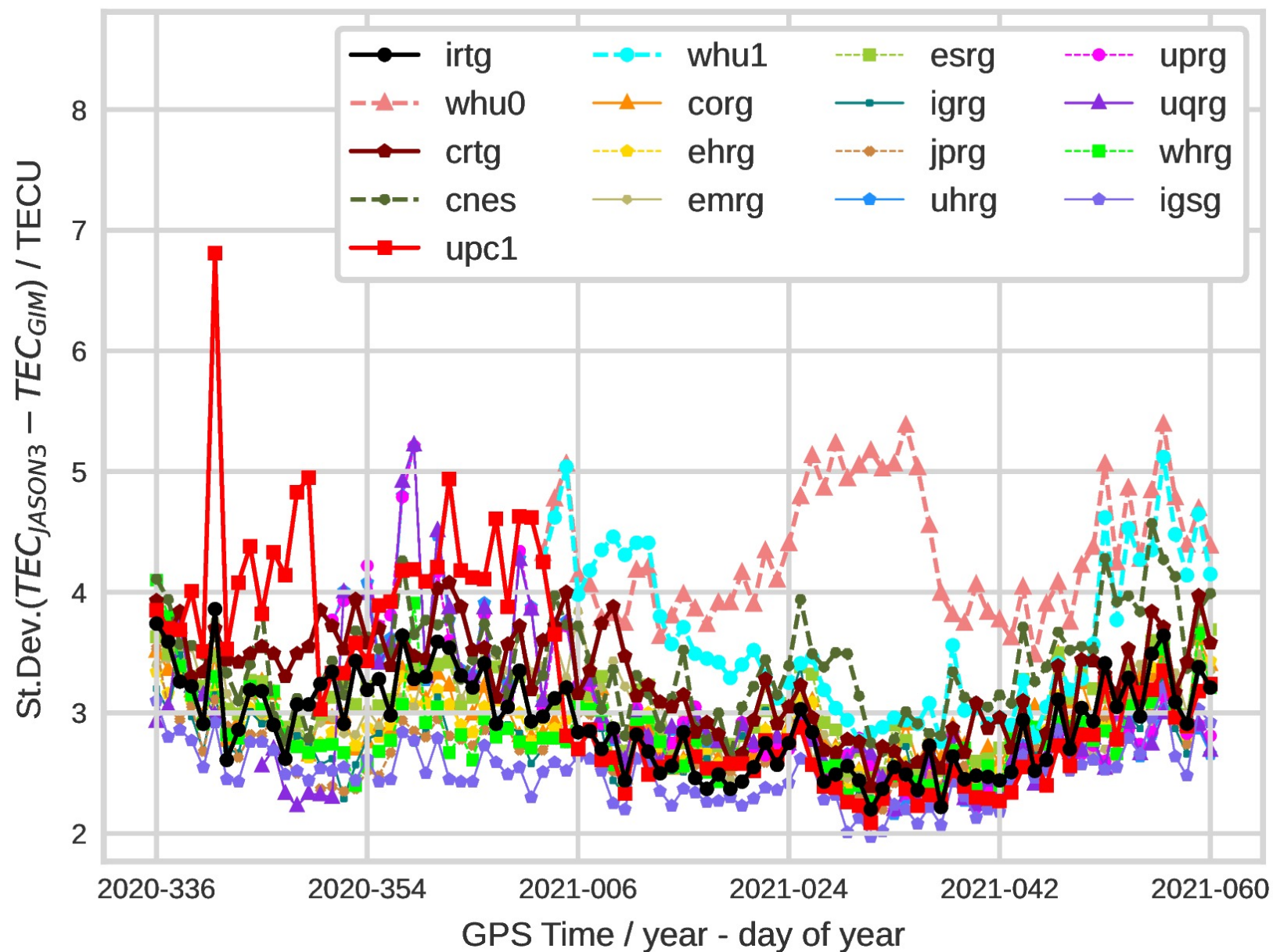
<https://link.springer.com/article/10.1007/s00190-020-01360-0>

[Zishen Li](#) , [Ningbo Wang](#), [Manuel Hernández-Pajares](#), [Yunbin Yuan](#), [Andrzej Krankowski](#), [Ang Liu](#), [Jiuping Zha](#), [Alberto García-Rigo](#), [David Roma-Dollase](#), [Heng Yang](#), [Denis Laurichesse](#) & [Alexis Blot](#)

Data flow for the IGS real-time combined GIM



The performance of GIMs versus Jason3-VTEC

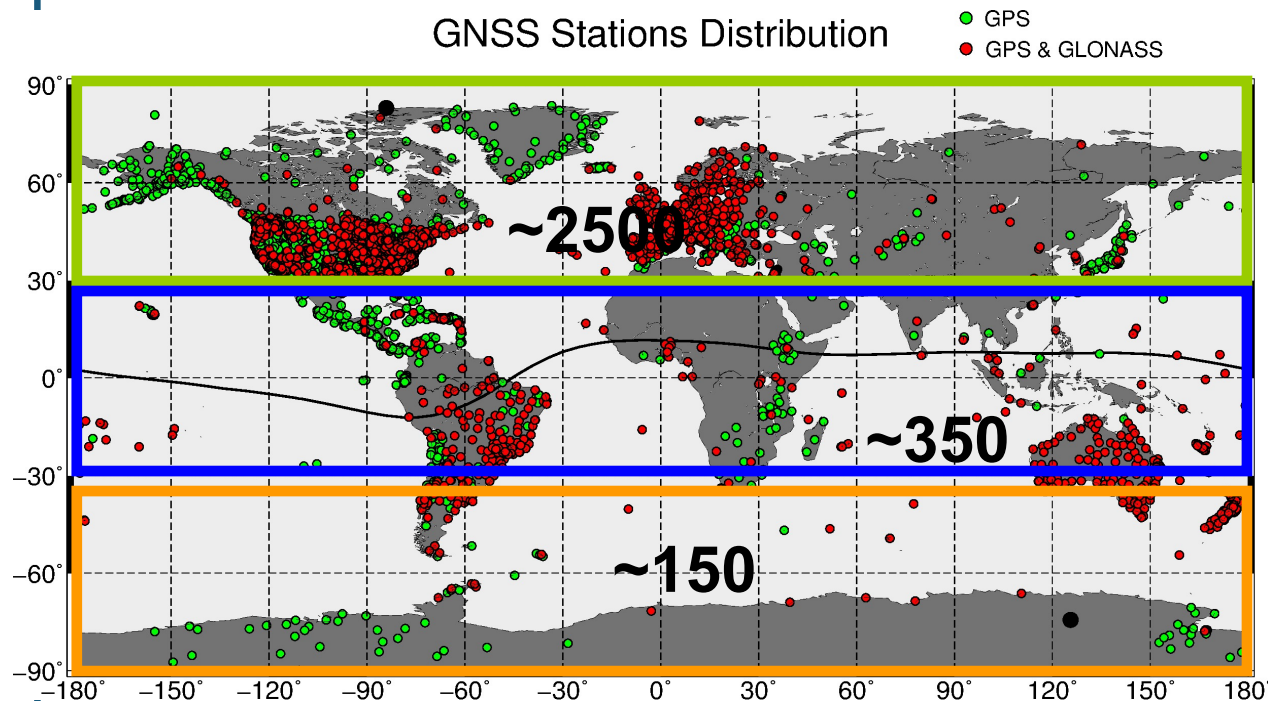


The current status of broadcasting IGS RT-GIMs

Agency	Temporal resolution	Broadcast frequency	Spherical harmonic degree	Mountpoints in NTRIP caster (in SSR format)	Real-Time IONEX files saved at FTP/HTTP
CAS	5 minutes	1 minute	15	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	ftp://ftp.gipp.org.cn/product/ionex/
CNES	2 minutes	1 minute	12	products.igs-ip.net:2101/SSRA00CNE1 products.igs-ip.net:2101/SSRA00CNE0 products.igs-ip.net:2101/SSRC00CNE1 products.igs-ip.net:2101/SSRC00CNE0	No
UPC-IonSAT	15 minutes	15 seconds	15	products.igs-ip.net:2101/IONO00UPC1	http://chapman.upc.es/ion/real-time/quick/
WHU	5 minutes	1 minute	15	58.49.58.150:2106/IONO00WHU0	ftp://igs.gnsswhu.cn/pub/whu/MGEX/realtime-ionex/
IRTG (IGS)	20 minutes	15 seconds	15	products.igs-ip.net:2101/IONO00IGS1	http://chapman.upc.es/irtg/

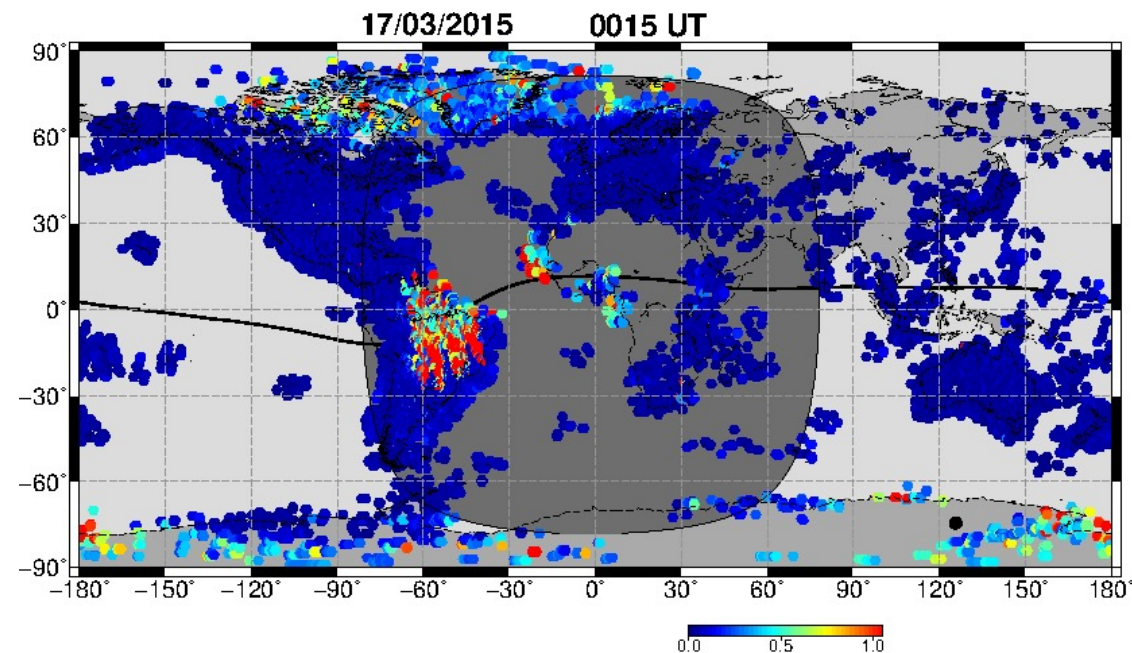
IGS ROTI Maps extension toward Southern Hemisphere and low latitudes

Main chalange – non uniform global distribution of permanent GNSS stations



Case of 2015 St. Patrick's Day storm

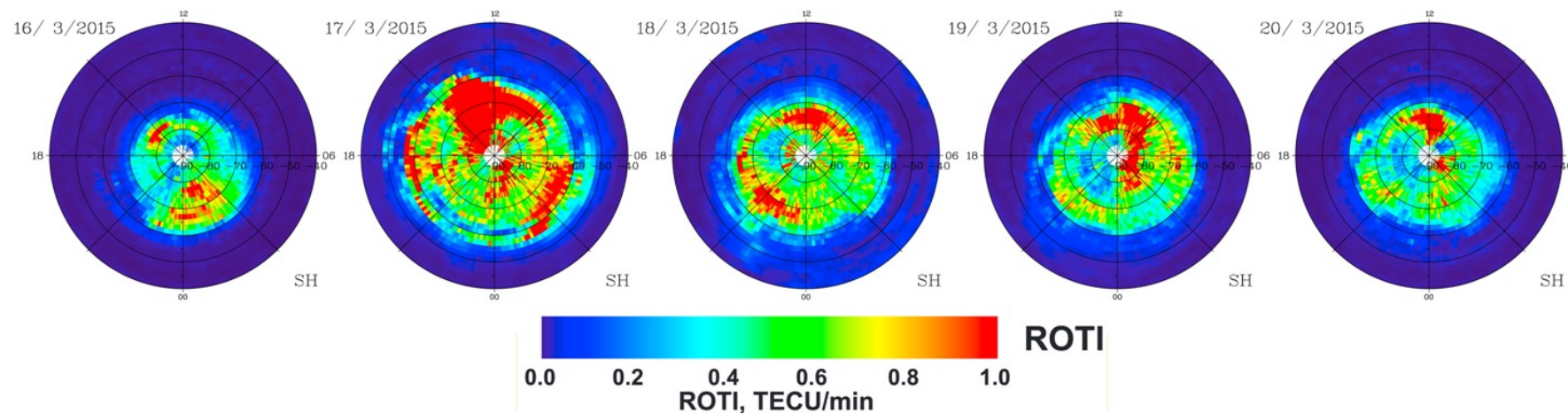
- ~ 5300 stations
~2000 multi-GNSS stations
(GPS + GLONASS+GALILEO+BEIDOU)
- ROTI maps with
time resolution 15 min
spatial resolution 2 x 2 degree



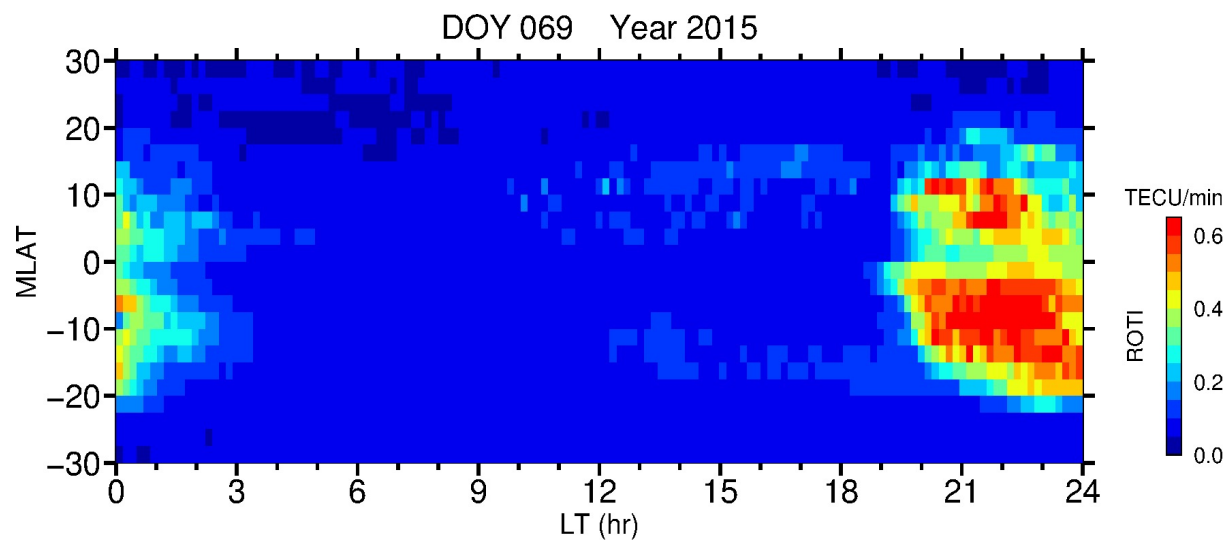
IGS ROTI Maps extension toward Southern Hemisphere and low latitudes

Preliminary results – ROTI maps on validation stage

ROTI Maps for Southern Hemisphere



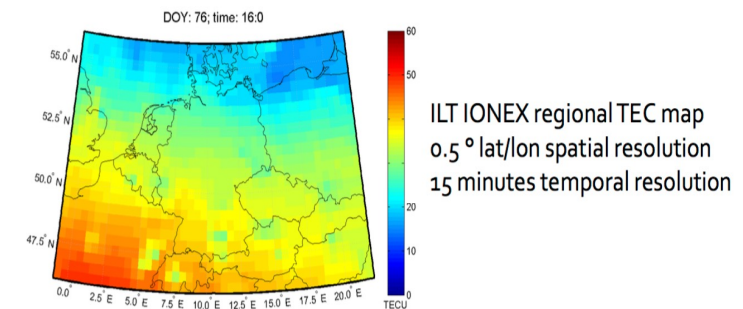
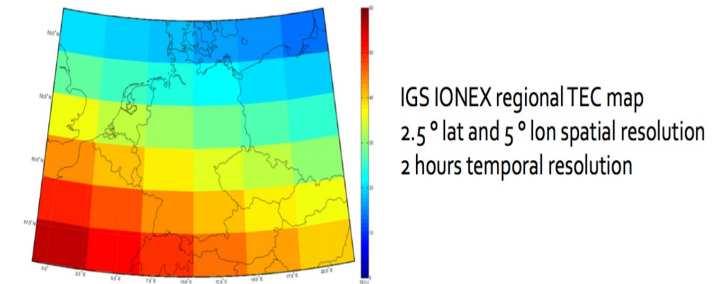
ROTI Maps for Low Latitudinal region



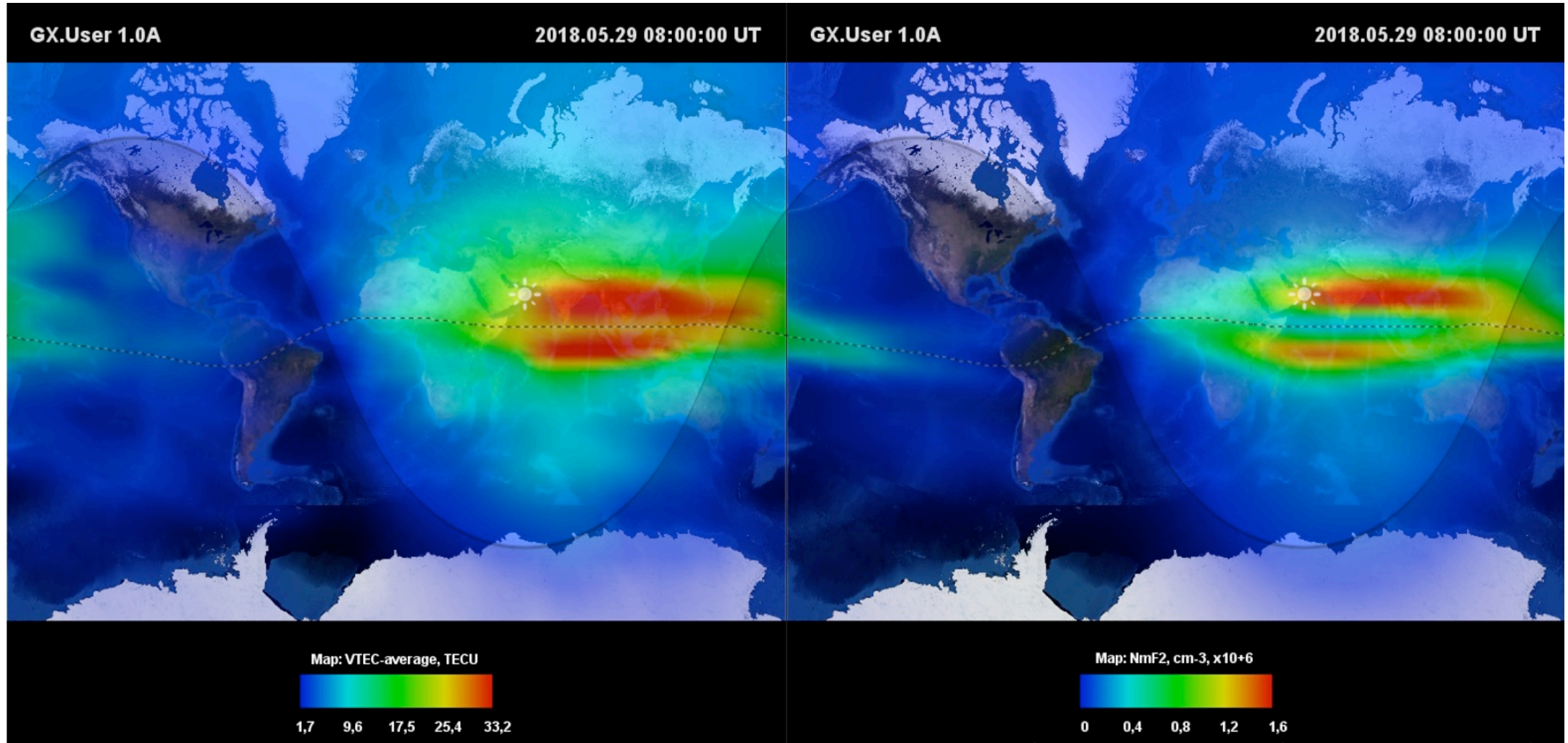
Cooperation with International LOFAR Telescope (ILT) for potential synergies

Comparison of IGS and ILT IONEX regional TEC maps

- The International LOFAR Telescope (ILT) has warmly acknowledged offer of preparing IGS ionospheric products dedicated to the ILT purposes.
- The activity is performed by UWM and UPC and also CAS in the future.
- The ILT-dedicated ionospheric product includes increased spatial and temporal resolution (0,5° latitudinal/longitudinal and 5 or 15 minutes in time). First regional TEC maps for the years 2012-2017 are being prepared.
- The new product significantly expanded group of scientific (geophysical and radioastronomical) users of the IGS ionospheric products.



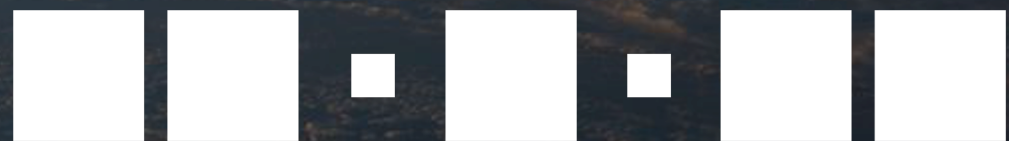
Cooperation with IRI COSPAR group for potential improvement of both IRI and IGS TEC



Comparison of climate VTEC and climate NmF2 as seen in GAMBIT Explorer. Climate VTEC derived from IGS network reflects expected quiet-time reference VTEC. Climate NmF2 from IRI model shows typical quiet-time plasma distribution.

Future Work

- Preparation of final version of IGS RT-GIMs
- Preparation of final version of IGS ROTI maps extension towards low latitudes and Southern Hemisphere
- Continuation of cooperation with IRI and ILT communities



IGS

INTERNATIONAL
GNSS SERVICE



Thank You!

Contact:

Andrzej Krankowski

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