IGS Ionospheric Working Group

Present and future IGS Ionospheric products

Andrzej Krankowski, Manuel Hernández-Pajares,

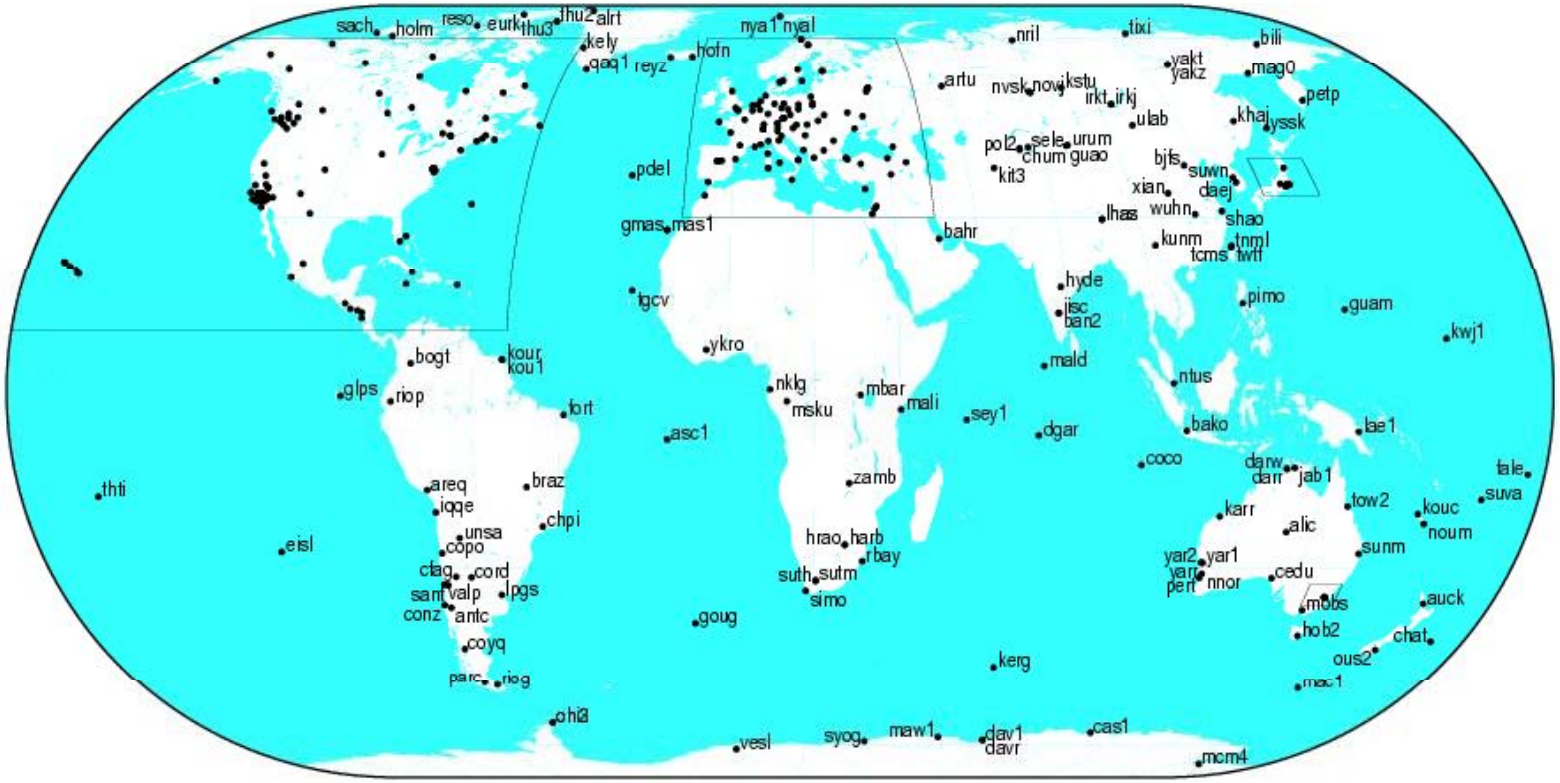
Joachim Feltens, Attila Komjathy, Stefan Schaer,

Alberto García-Rigo, Pawel Wielgosz

Outline

- Introduction
- IGS IONO WG activities
- Current performance of IGS global TEC maps
- Updates and future plans
- Summary

International GNSS Service - IGS



IGS directly manages ~400 permanent GNSS stations observing 4-12 satellites at 30 s rate: more than 250,000 STEC observations/hour worldwide, but there is lack of stations at some areas (e.g., over the oceans)

IGS IONO WG activities

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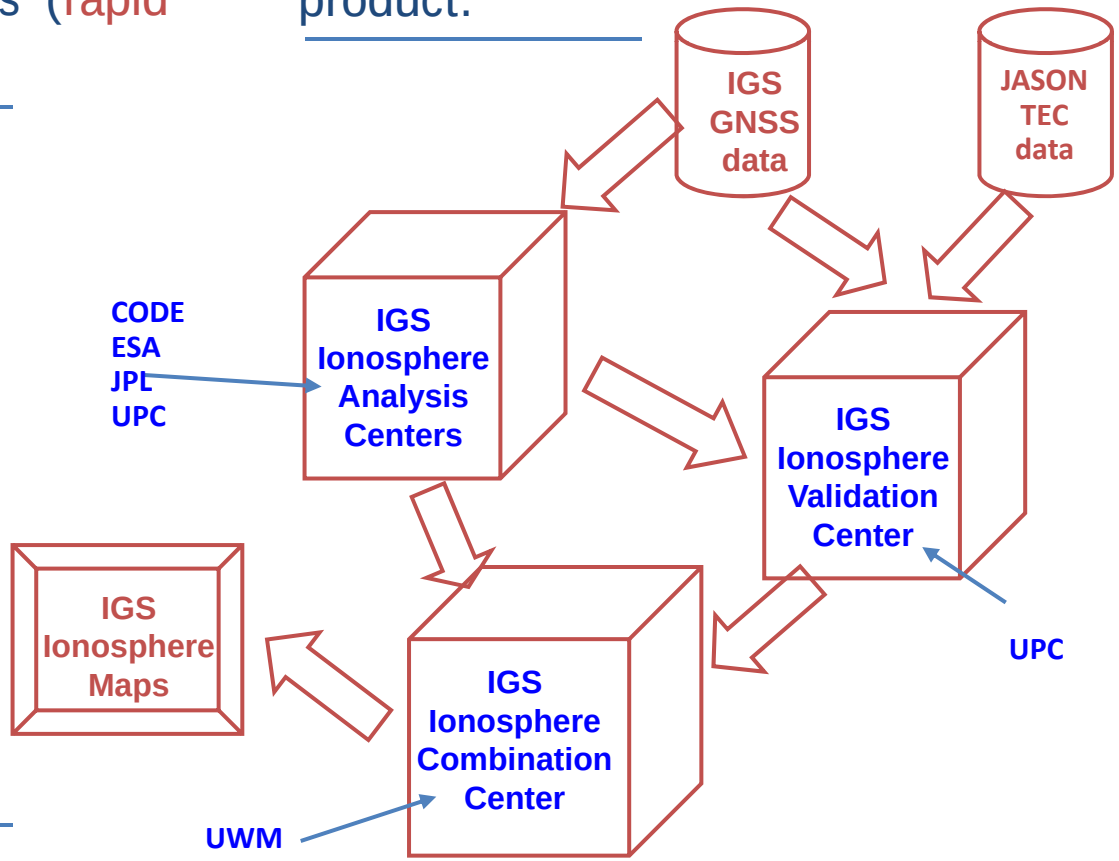
The IGS Ionosphere Working group started its activities in June 1998 with the main goal of a routinely producing IGS Global TEC maps.

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:

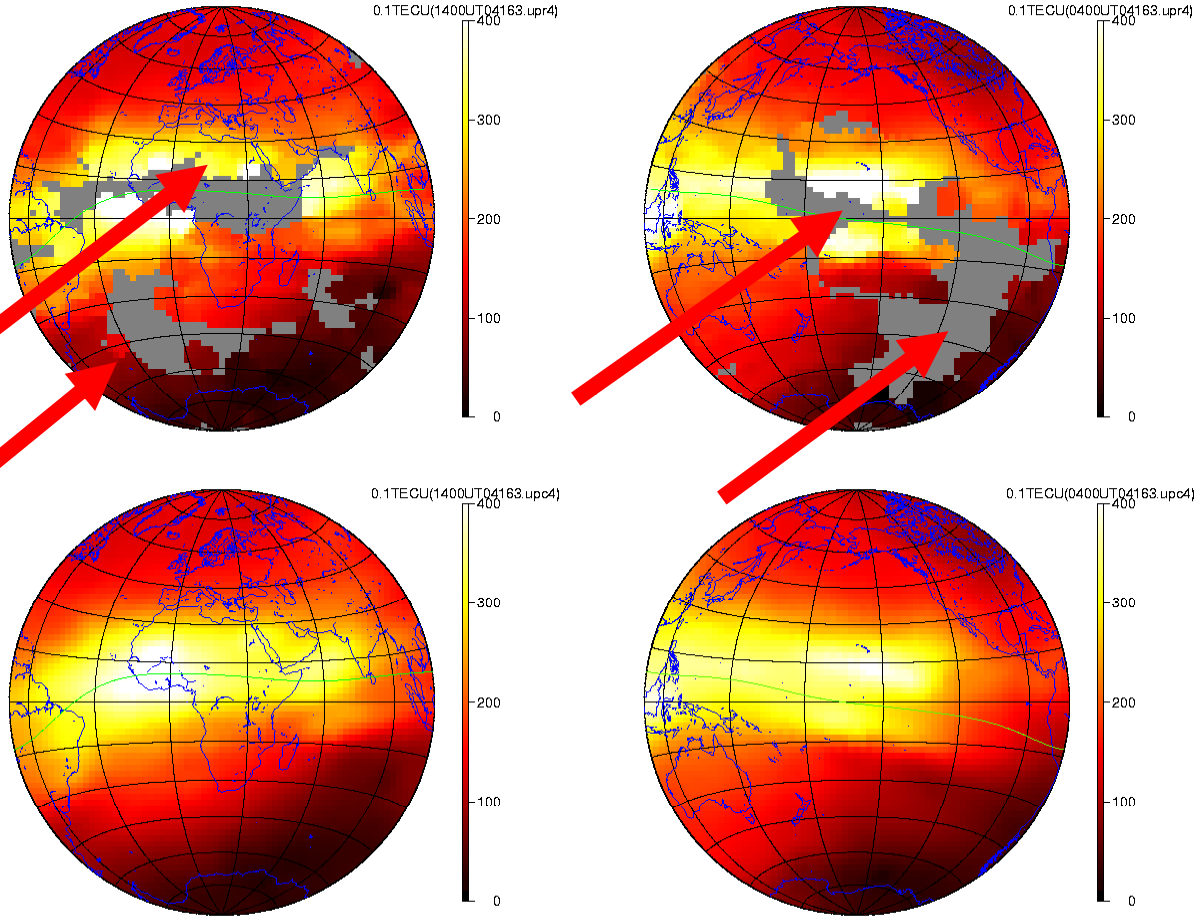
1. Dr Joachim Feltens, ESA 1998–2002,
2. Dr Manuel Hernández-Pajares, UPC, 2002–2007
3. Dr. Andrzej Krankowski, UWM, 2008-

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.



Determining VTEC in a global network: main problem: lack of data - South and Oceans

It can be seen that the typical “holes” appearing at the first stage of the global maps computation (each 2 hours). This requires an optimum spatial-temporal interpolation technique to cover all the Ionosphere.



Lack of data over the equatorial Africa and Atlantic, and in part over equatorial and southern Pacific, hamper the detection of the equatorial anomalies (June 13, 2004).

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Example of IGS Final GIM: 2010-141 DOY

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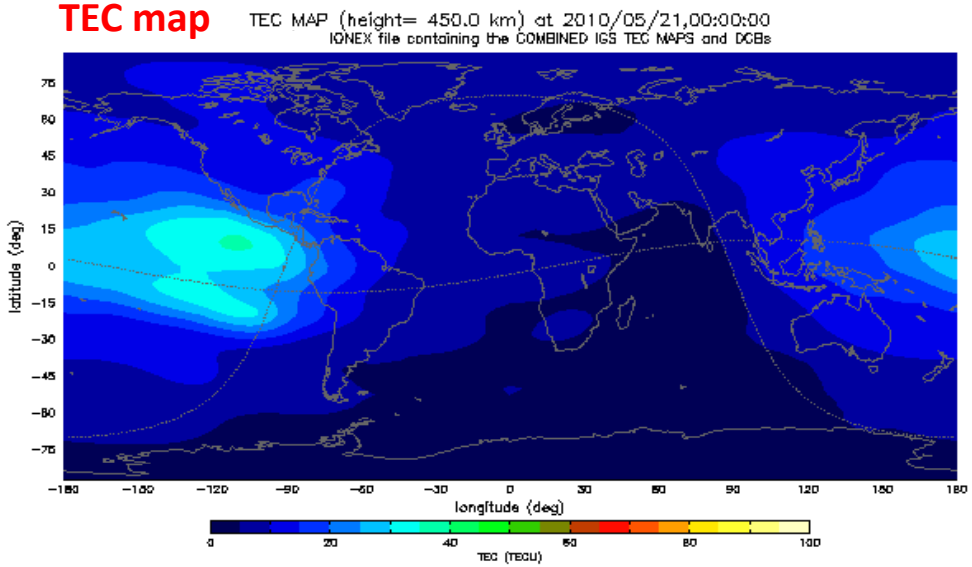
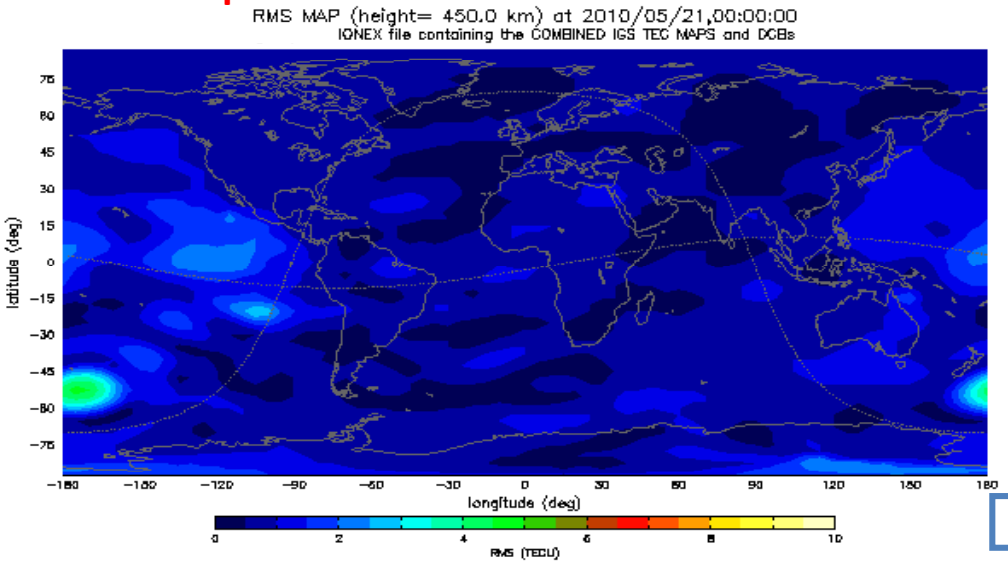
TEC map



RMS map



4 Analysis Centers (CODE, ESA, JPL, and UPC) and a Validation Center (UPC) 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.

Units: TECU

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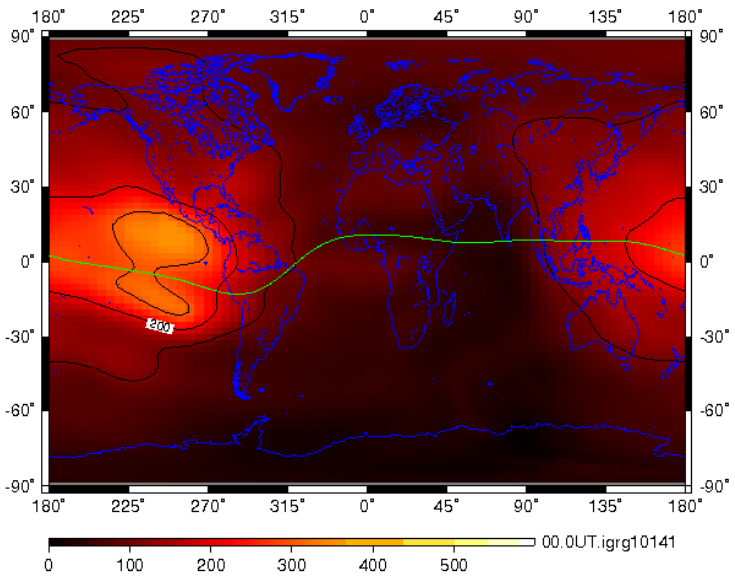
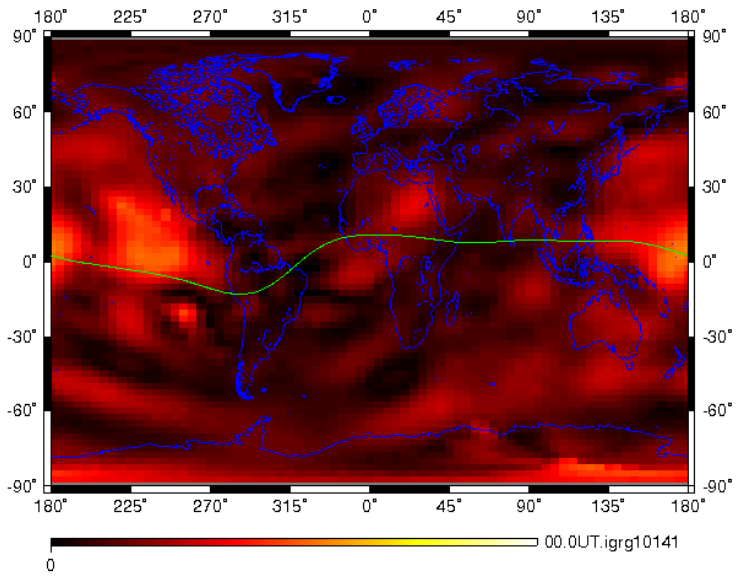
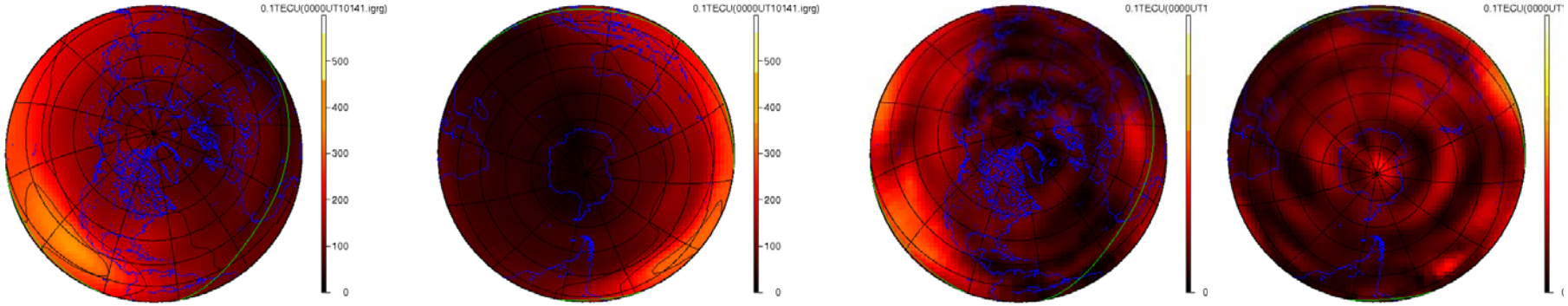
Example of IGS RAPID GIM: 2010-141 DOY

TEC maps



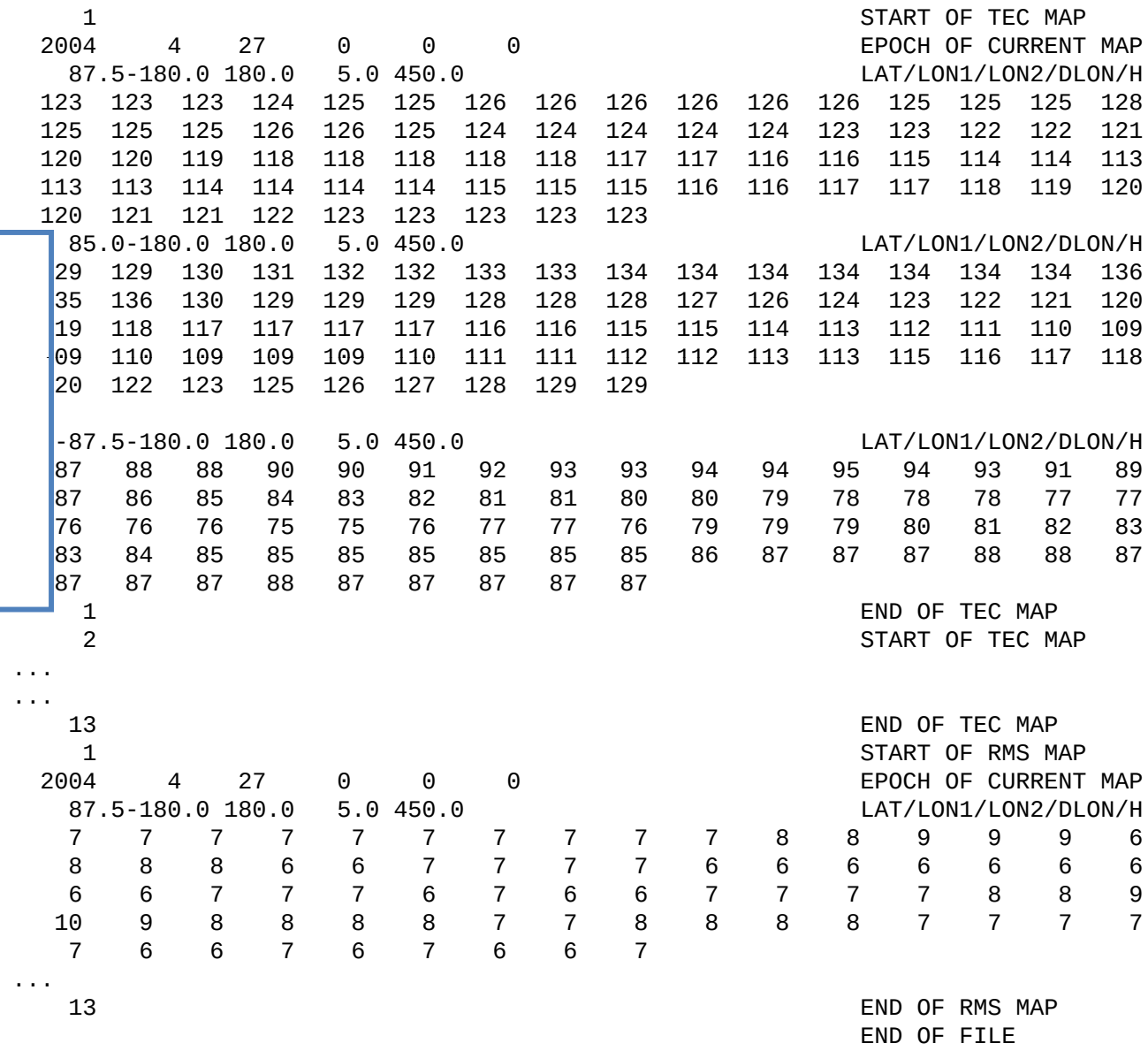
RMS maps





Units: 0.1 TECUs

The IONEX format body



The **IONEX** (IONosphere inter EXchange) format allows to store the VTEC and its error estimates in a grid format.

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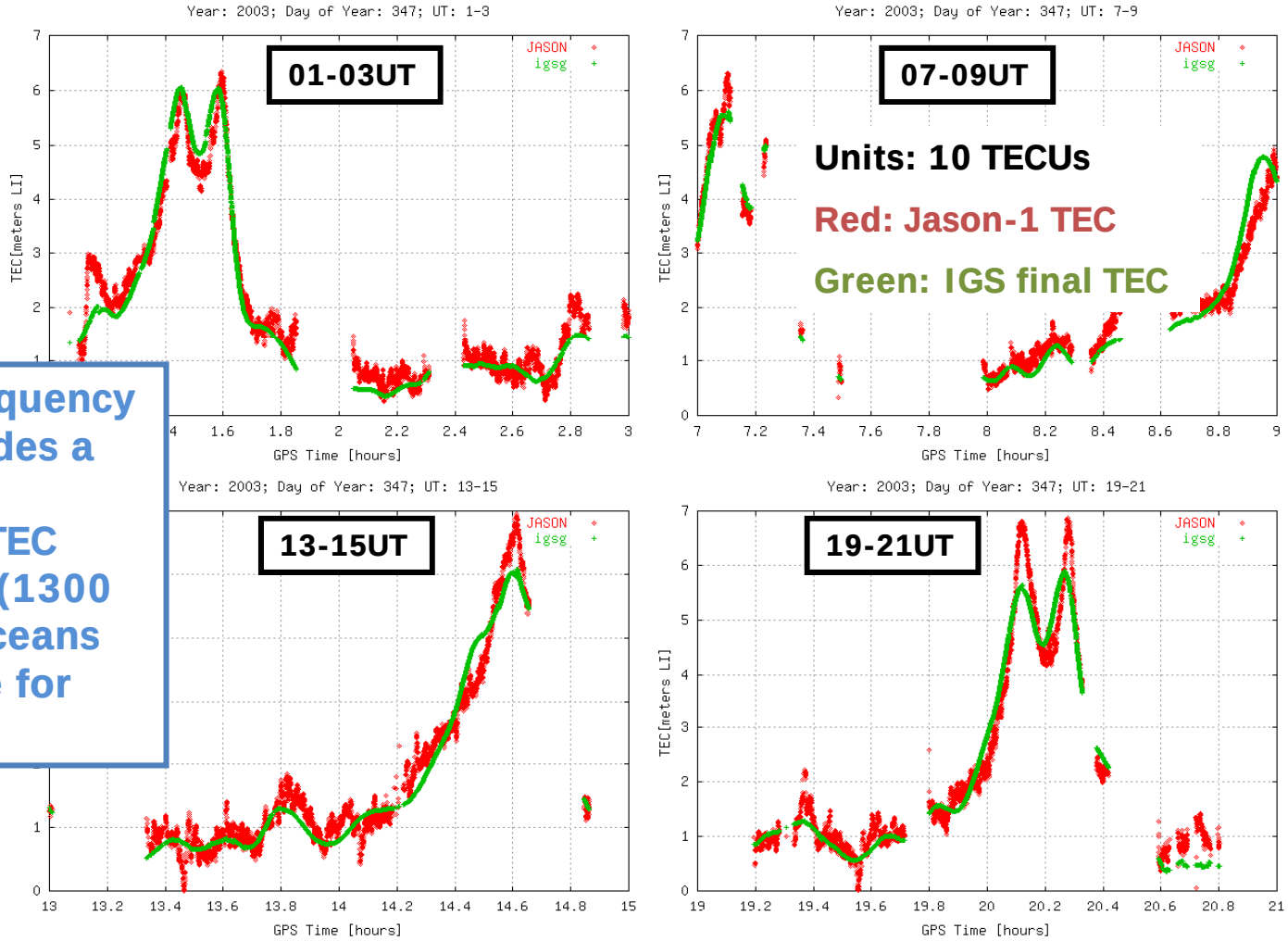
Overall validation of VTEC maps during more than 10 years of IGS Iono WG operations

Example of comparison of IGS vs JASON: 2003-347



JASON dual frequency altimeter provides a direct and independent VTEC below its orbit (1300 km) over the oceans (the worst case for GPS).

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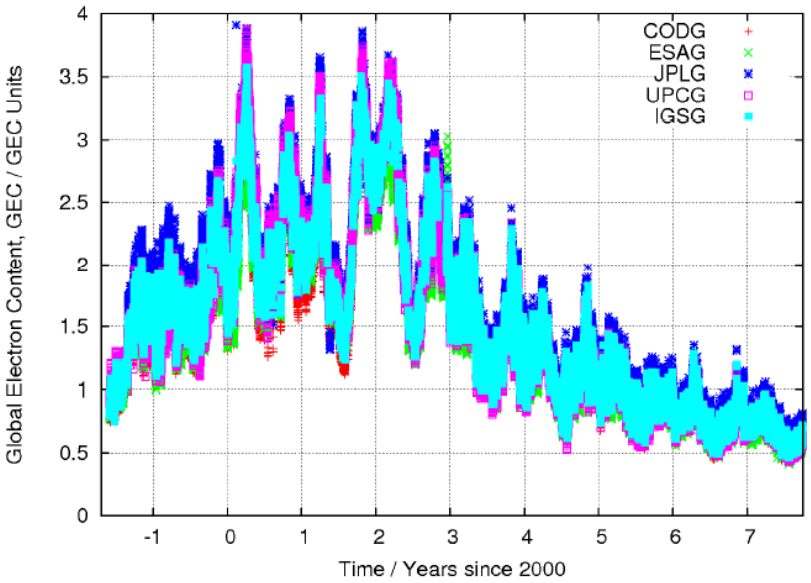
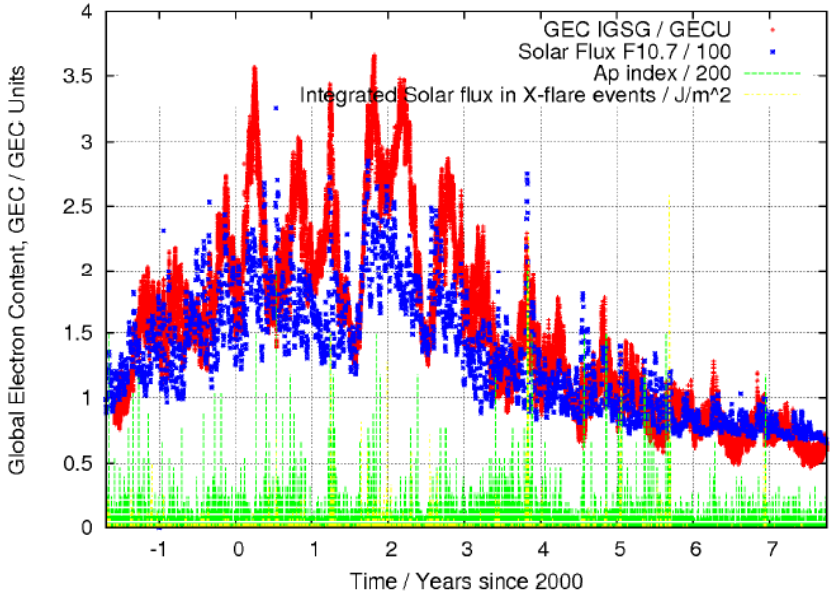
Overall validation of VTEC maps during more than 10 years of IGS Iono WG operations

Evolution of Global Electron Content during more than 10 years of IGS final VTEC maps

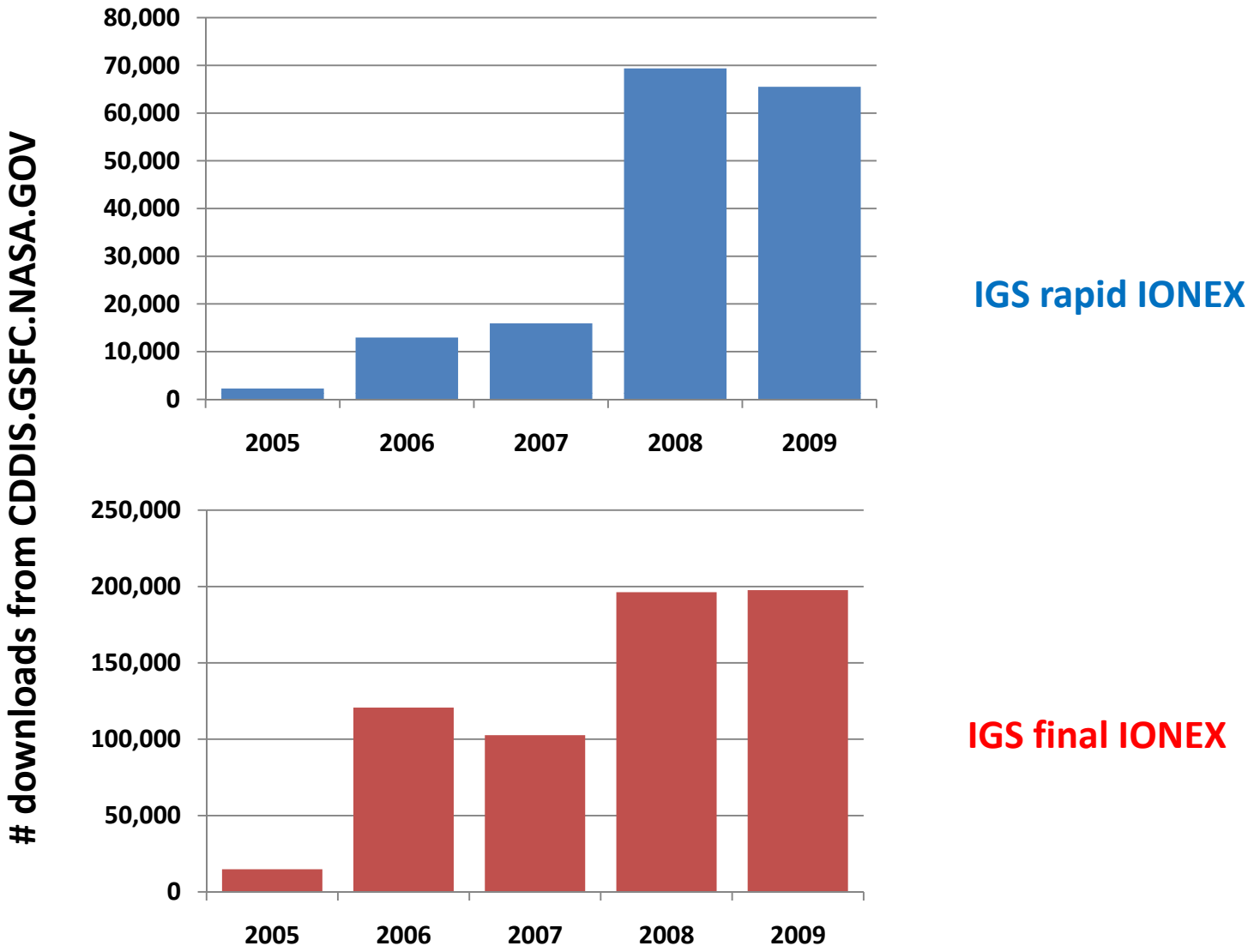




Global Electron Content evolution during the availability of IGS Ionospheric products, since June 1998 (source: Final IGS VTEC maps).

Global Electron Content evolution during the availability of IGS Ionospheric products, vs. Solar Flux, Ap index and Xray flux, since June 1998.

IGS IONEX usage statistics for both final (IGSG) and rapid (IGRG) VTEC maps



IGS rapid IONEX

IGS final IONEX

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Current updates and future plans of IGS IWG

The following actions to be considered:

- Higher temporal resolution < 1 hour (asap)

- Predicted TEC maps – 1 and 2 days ahead
  - since October 2009 UPC and ESA have provide predicted maps
  - combined product to be started (end of 2010)

- The old procedures have been rewritten (perl) and currently running in parallel

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-Cooperation with International Reference Ionosphere (IRI)

- Cooperation with National Central University (Taiwan) on application of COSMIC occultation data

- Space Weather monitoring over polar regions

Comparison of IRI Global TEC maps with IGS final GIMs

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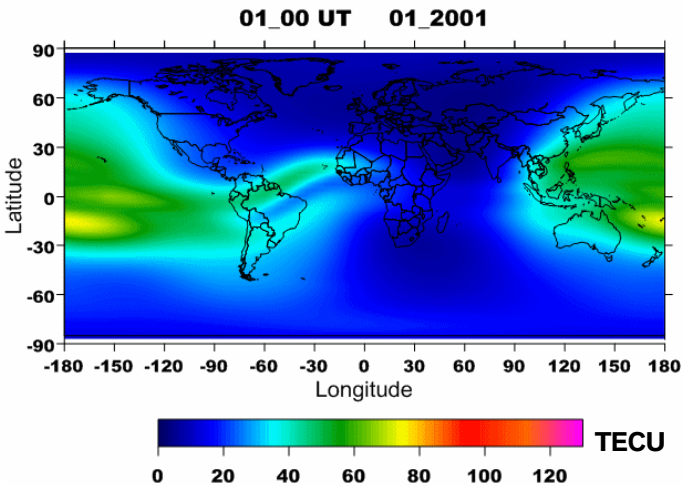
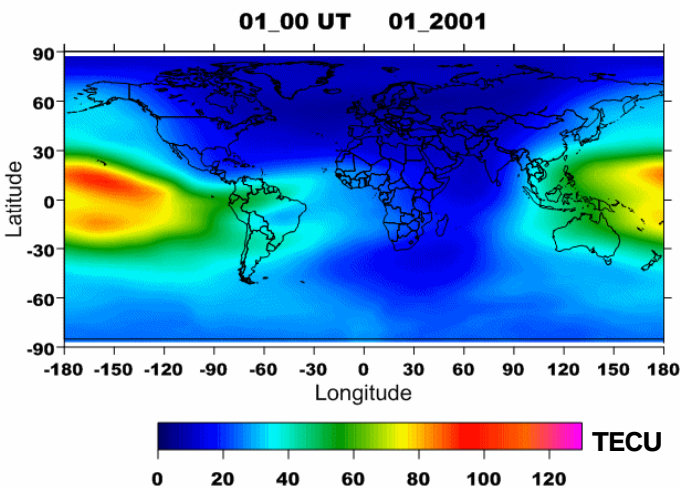
IRI

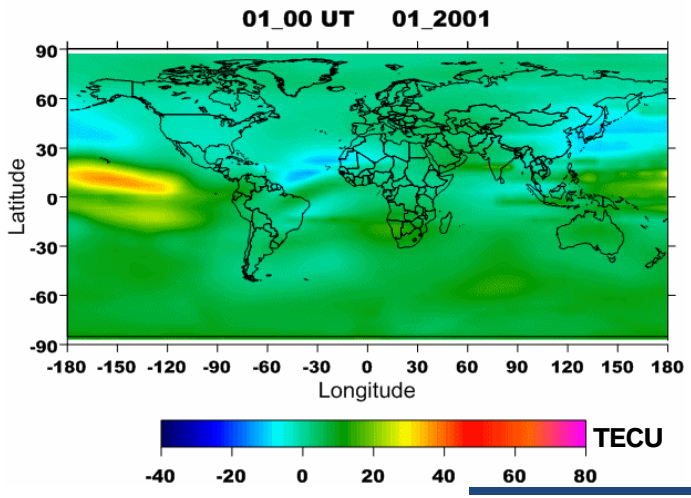


2001

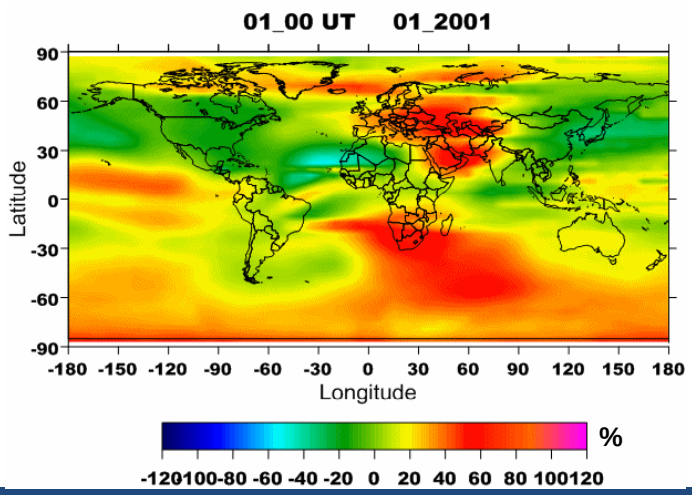
IGS IONEX



IGS IONEX - IRI (TECU)



IGS IONEX - IRI (%)



Comparison of IRI Global TEC maps with IGS final GIMs

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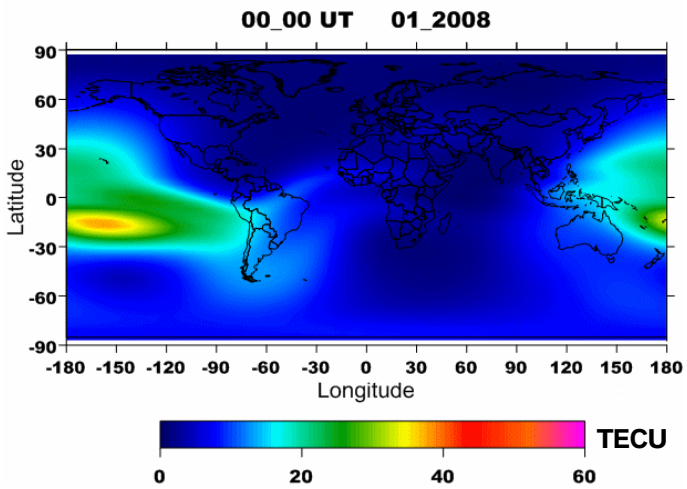
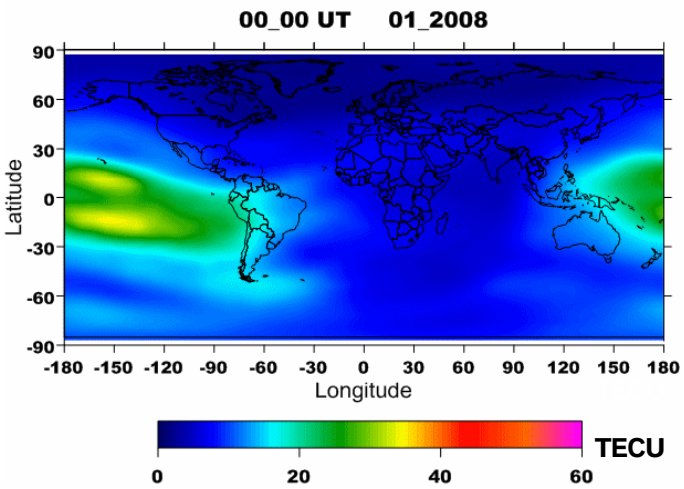
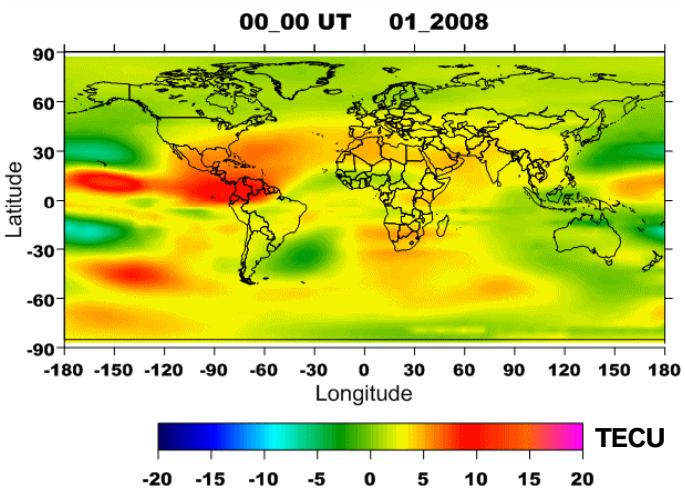
IRI 2008 IGS IONEX

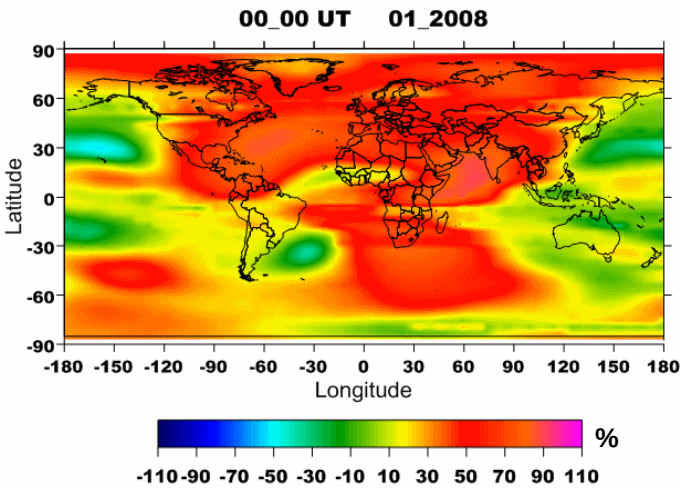




IGS IONEX - IRI (TECU)



IGS IONEX - IRI (%)



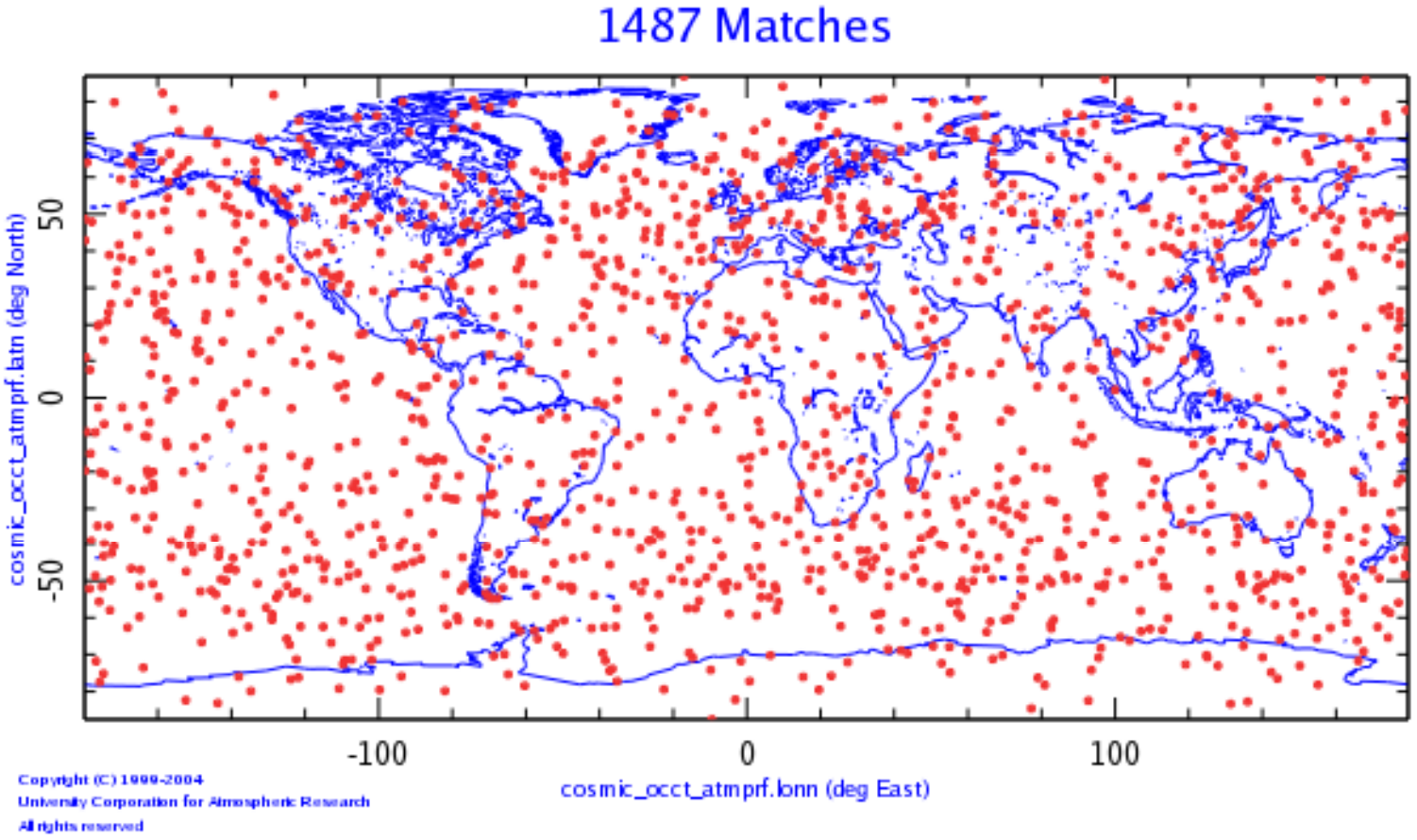
FORMOSAT-3/COSMIC

- ***FORMOSAT-3/COSMIC Constellation was launch at 01:40 UTC, April 14, 2006 (Taiwan Time: April 15 2006) at Vandenberg Air Force Base, CA.*** *Minotaur Launch*

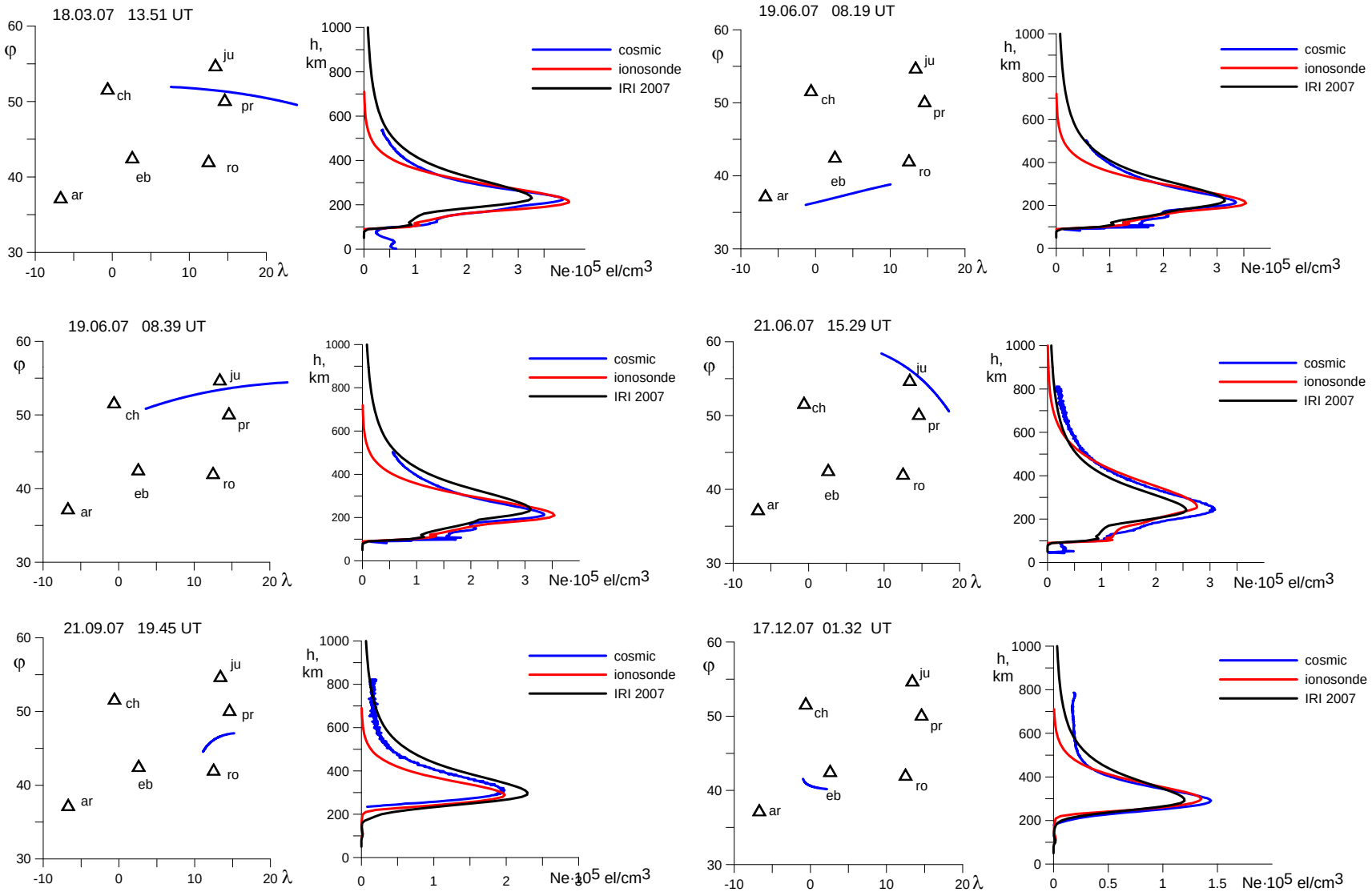
- ***Maneuvered into six different orbital planes (inclination ~72°) for optimal global coverage (at ~800 km altitude).***

- ***All satellites are in good health and providing science data.***

Occultation locations for COSMIC, 24 Hrs (28.03.2008)



Comparison of IRI profiles with COSMIC and ionosonde data (DIAS)



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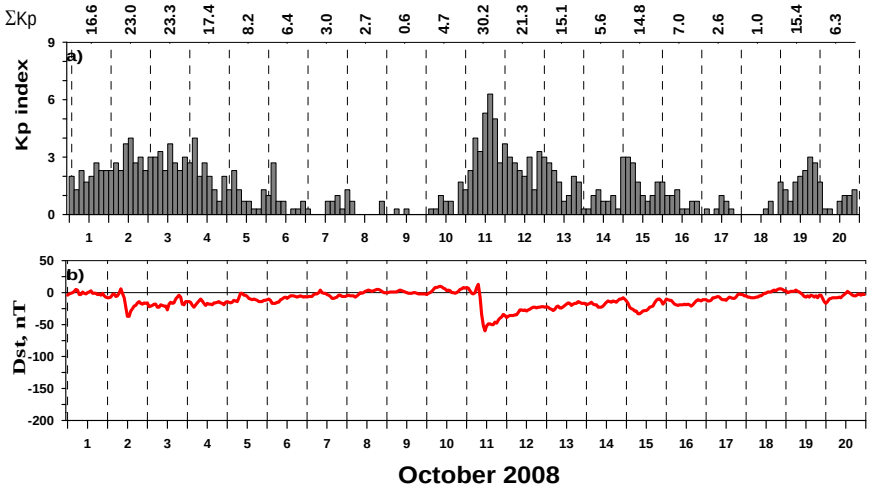
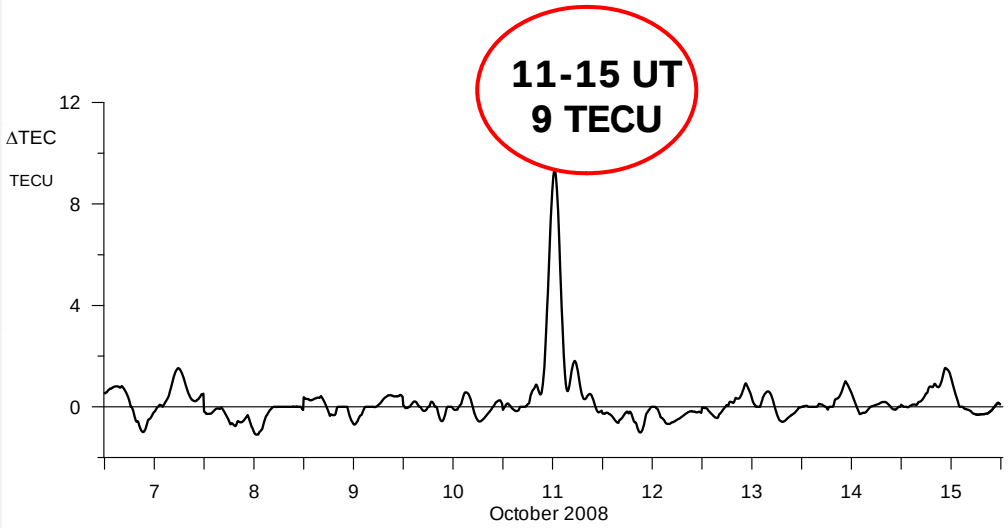
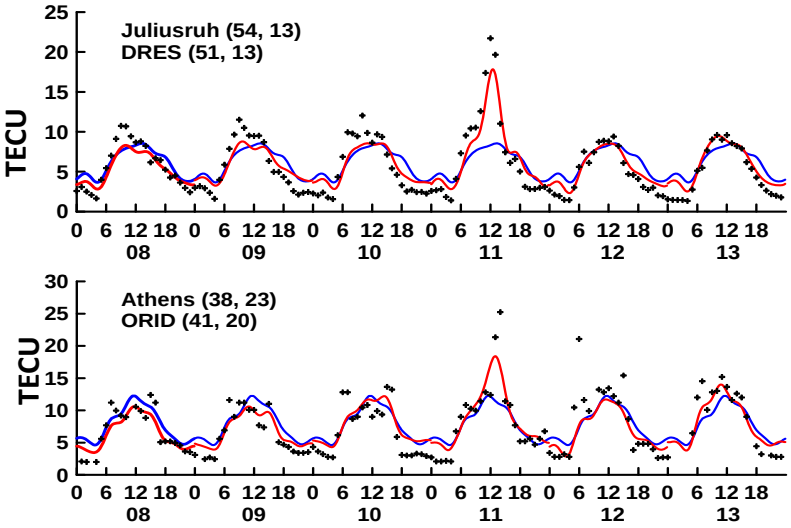
IGS Workshop
28 June - 2 July 2010, Newcastle upon Tyne ○ England

Ex. Geomagnetic Disturbance in October 2008







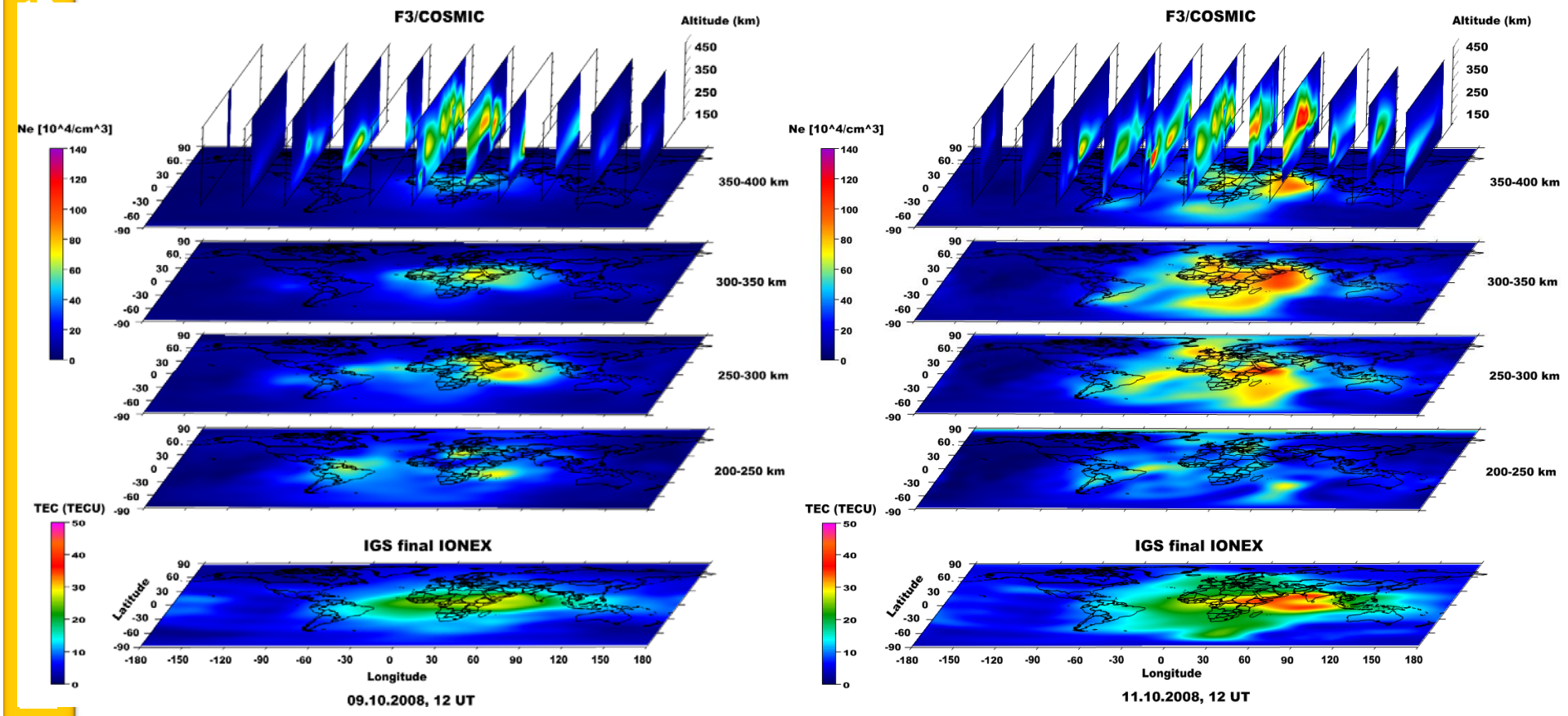
Diurnal variations of TEC (red line) over DRES and ORID IGS GPS stations. The crossed line indicates variations of $(foF2)^2/3$ over Juliusruh and Athens ionosondes. Blue line corresponds to the average TEC variation

Comparison F3/COSMIC electron density with IGS final TEC maps

9 October 2008 – quiet day

11 October 2008 – disturbed day

12 UT

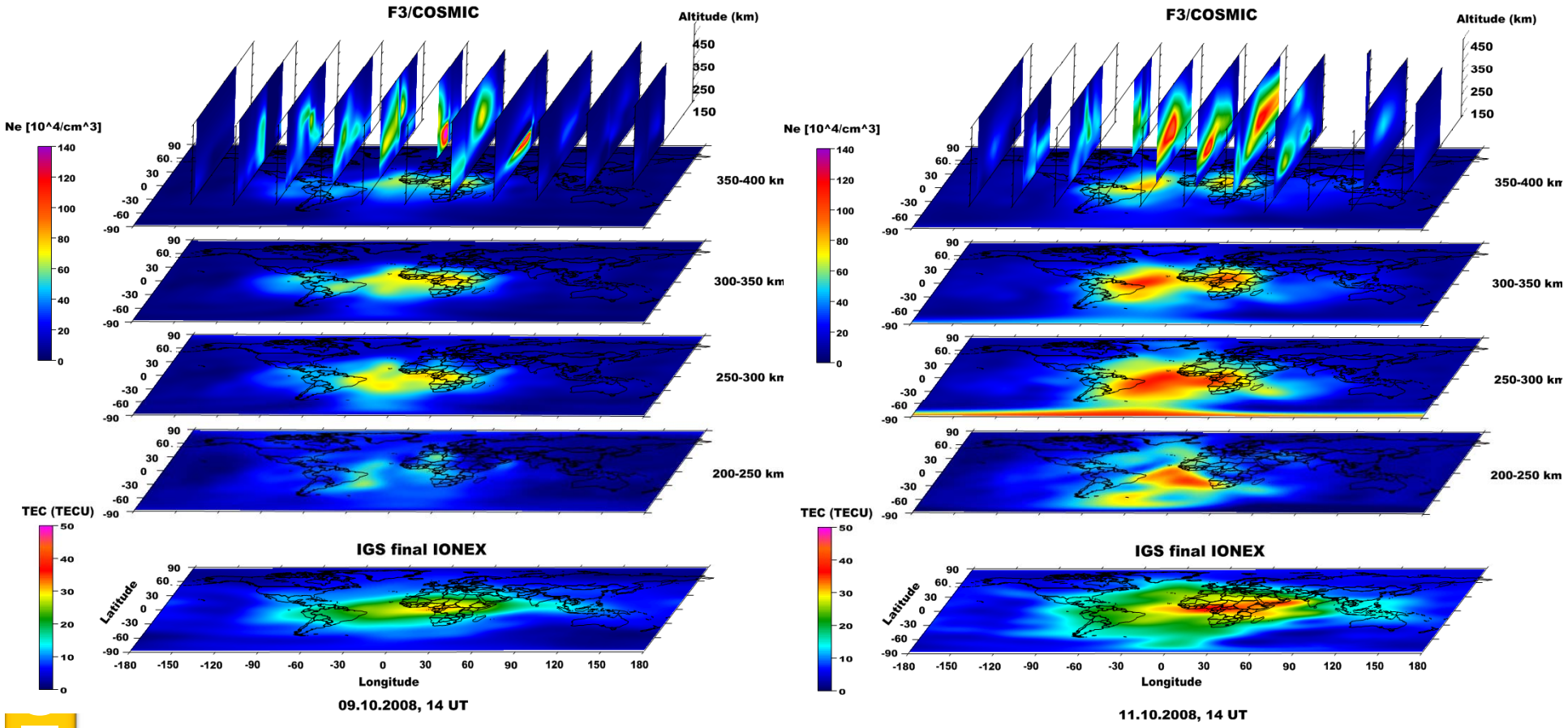


Comparison F3/COSMIC electron density with IGS final TEC maps

9 October 2008 – quiet day

14 UT

11 October 2008 – disturbed day



Space Weather monitoring over polar regions

High latitude TEC fluctuations

For fast detecting phase fluctuation occurrence the rate of TEC (dTEC/dt) is more preferred:

$$ROT = 9.52 \cdot 10^{16}\ \text{el/m} \cdot (\Delta\Phi_i - \Delta\Phi_k)$$

$\Delta\Phi_{ki}$ - differential carrier phase sample with 30 sec interval

$$\Delta t = t_k - t_i = 1\ \text{min.}$$

As a measure of ionospheric activity we used also the Rate of TEC Index (ROTI) based on standard deviation of ROT:

$$ROTI = \sqrt{\langle ROT^2 \rangle - \langle ROT \rangle^2}$$

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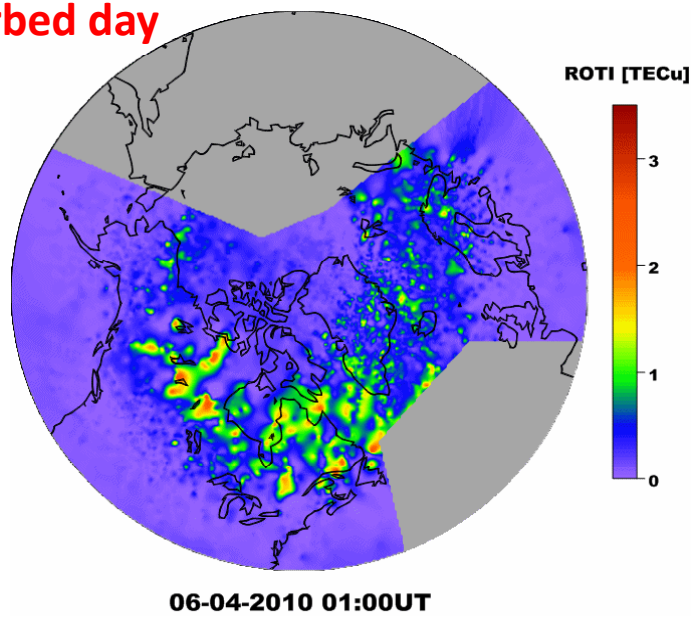
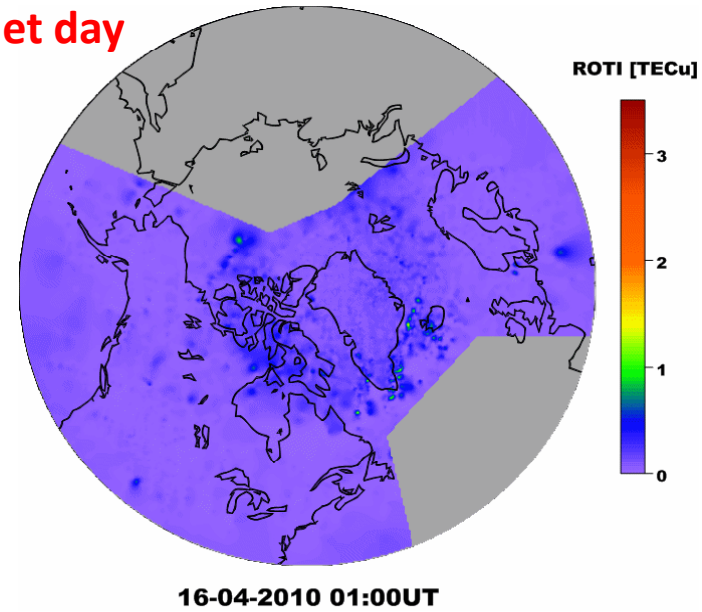
Oval of irregularities

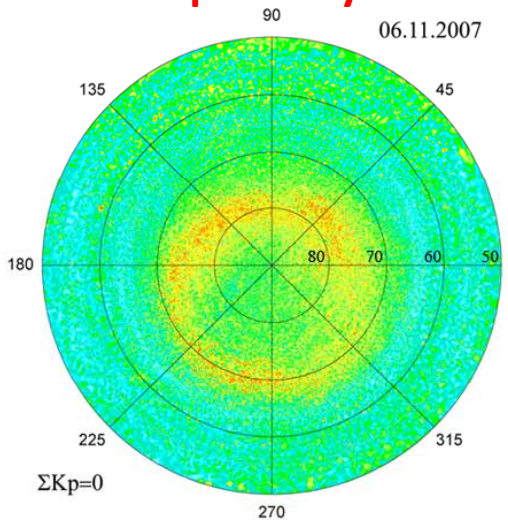
disturbed day



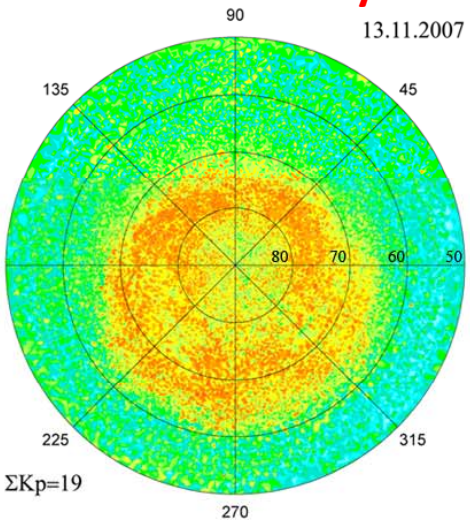
quiet day



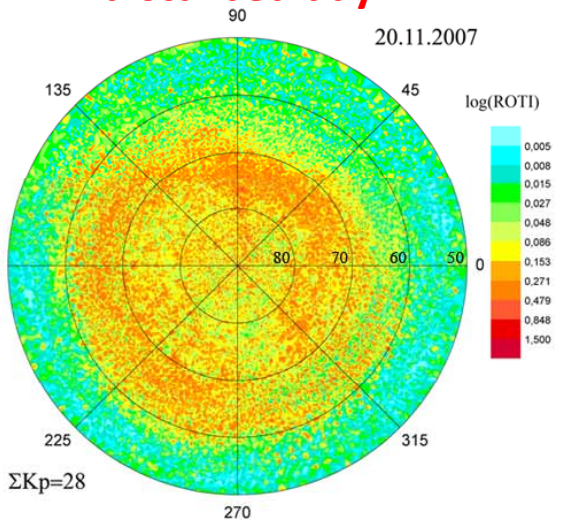
quiet day



disturbed day



disturbed day



Dynamic of the irregularity oval for quiet and disturbed days.

Summary of Iono WG activities

1. Long series of IGS VTEC maps offers a very good source of information about the ionosphere with high spatial and temporal resolution

2. Future improvements are determined by users' requirements (the number of users has significantly increased during the last 10 years)

   A good example is the recent interest of ESA SMOS mission in using IGS final and predicted VTEC maps

3. 12 years of continuous time series of TEC measurements may be applied to update ionospheric models, e.g., IRI model

4. COSMIC occultation data gives a new opportunity to study/model the ionosphere and to validate IGS TEC maps

Summary of Iono WG activities

5. A long time series of accurate global VTEC values are freely available since 1998 for scientific or technical use, with latencies of about 12 days (final product) or 1 day (rapid product). Thanks to the cooperative effort developed within the IGS framework and the international scientific community this open service will hopefully continue its evolution during the next years, sensitive to both new user needs and scientific achievements.