

Real-Time and Ionosphere in the IGS

G. Beutler

*Astronomical Institute, University of Bern
IAG representative on PNT Advisory Board*

**15th Meeting of the National Space-Based Positioning,
Navigation, and Timing (PNT) Advisory Board**

June 11-12, 2015

Marriott Annapolis

80 Comprise Street

Annapolis, MD21401

International Association of Geodesy



Content

- **The IGS**
- **IGS Workshop 2014 in Pasadena, California**
- **IGS-RTS (Real Time Service)**
- **IGS ionosphere monitoring & Low Earth Orbiters (LEOs)**

The IGS

The creation of the IGS was **initiated in 1989** with I.I. Mueller, G. Mader, B. Melbourne, and **Ruth Neilan** as protagonists.

The IGS became an **official IAG service** in 1994.

The IGS first was a pure **GPS Service**, it was renamed as the **International GNSS Service** in 2004.

Today the IGS is a truly **interdisciplinary, multi-GNSS service in support of Earth Sciences and Society.**

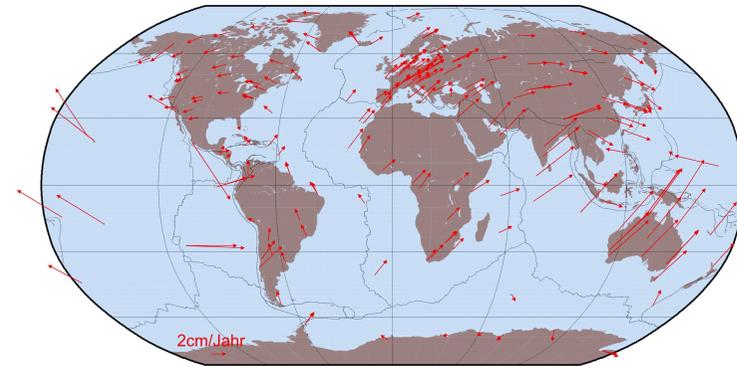
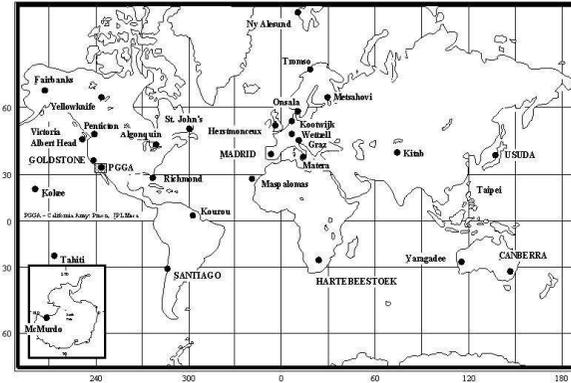
Since its creation the **IGS Central Bureau** is located in the USA with **Ruth Neilan** as director – who stands for **continuity and leadership.**

International Association of Geodesy



The IGS

Station Locations for the IGS Pilot Campaign, 1992



Monitor station motion
in „real time“



IGS Network in June 2015

In 1992 the IGS was based on about 20 geodetic receivers, 400+ receivers are active and their data retrievable today

International Association of Geodesy



The IGS

In 1992 the IGS started off as an orbit determination service (dm accuracy) for about 15-20 GPS satellites.

Today, the IGS provides **ephemerides** (accurate to 2-4 cm) for **32 GPS satellites** and for **24 GLONASS satellites** (accurate to 5-8 cm), i.e., for all currently active **GNSS satellites**.

In addition, the IGS provides

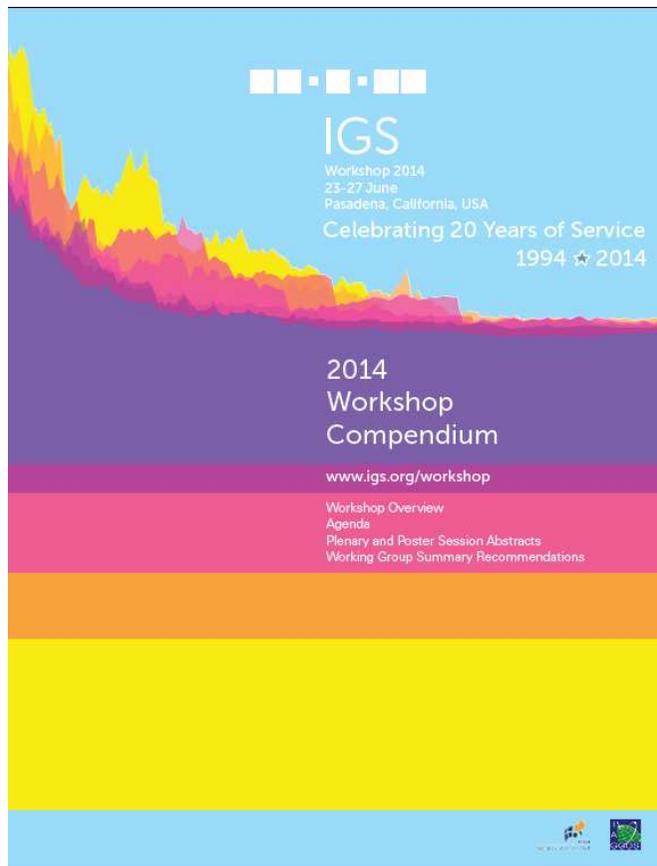
- archive of all globally relevant GNSS observations since 1991
- satellite and receiver clock corrections (sub-ns accuracy)
- polar motion (PM) and length of day (lod) (cm accuracy)
- coordinates and velocities for 200+ sites (cm / mm/y accuracy)
- atmosphere information, in particular **Global Ionosphere Models (GIMs)**.
- Satellite clock corrections & corresponding orbits are provided in „real time“ based on the IGS Real Time Network of 150+ sites.

All IGS products are **accurate**, **reliable** and **robust**, due to mutual **validation** and **combination** of agency-specific products, and they are available in a **timely** manner.

International Association of Geodesy



IGS Workshop 2014



Message from the Director of the IGS Central Bureau

Dear Workshop Attendee,

Thank you for participating in the IGS Workshop 2014, held on the campus of the California Institute of Technology (Caltech) in Pasadena, California, USA. This special twentieth anniversary workshop was hosted by the IGS Central Bureau, with support from the NASA Jet Propulsion Laboratory (JPL) and Caltech.

The week-long workshop featured plenary presentations and posters presented by our colleagues from around the world – illustrating how the IGS is truly an international organization serving science, engineering, and society in general.

The local organizing committee was led by Ruth Neilan (JPL) and Steve Fisher (JPL), with support from members of the IGS Central Bureau. The scientific program committee was led by Rolf Dach (AIUB), Shailen Desai (JPL), and Andrzej Krankowski (UWM).

In addition to plenary and poster presentations, we were able to celebrate twenty years of service with a special Anniversary Colloquium. This event featured many of our colleagues reflecting on various points in IGS history, as well as their own thoughts on the future of the IGS and geodesy.

All plenary session presentations were videorecorded, and are available to view on the "Presents" section of the IGS website: www.igs.org/presents. All presentations and posters are available in PDF format for download from the IGS website, as well.

Thank you for attending, and we look forward to seeing you again in 2016!

Ruth Neilan
IGS Central Bureau Director
Head of the Local Organizing Committee

<http://kb.igs.org/hc/en-us/articles/204895687-2014-Workshop-Compendium>

International Association of Geodesy



In summary the IGS is ...

- ... the **premier source** of the highest-quality GNSS data, products, and related standards and conventions
- ... a **scientific Service** of the International Association of Geodesy (**IAG**) since 1994
- ... a **federation** of more than 200 institutions and organizations worldwide
- ... following an open **data policy**

International Association of Geodesy



IGS Real Time Service

International effort of many contributions:

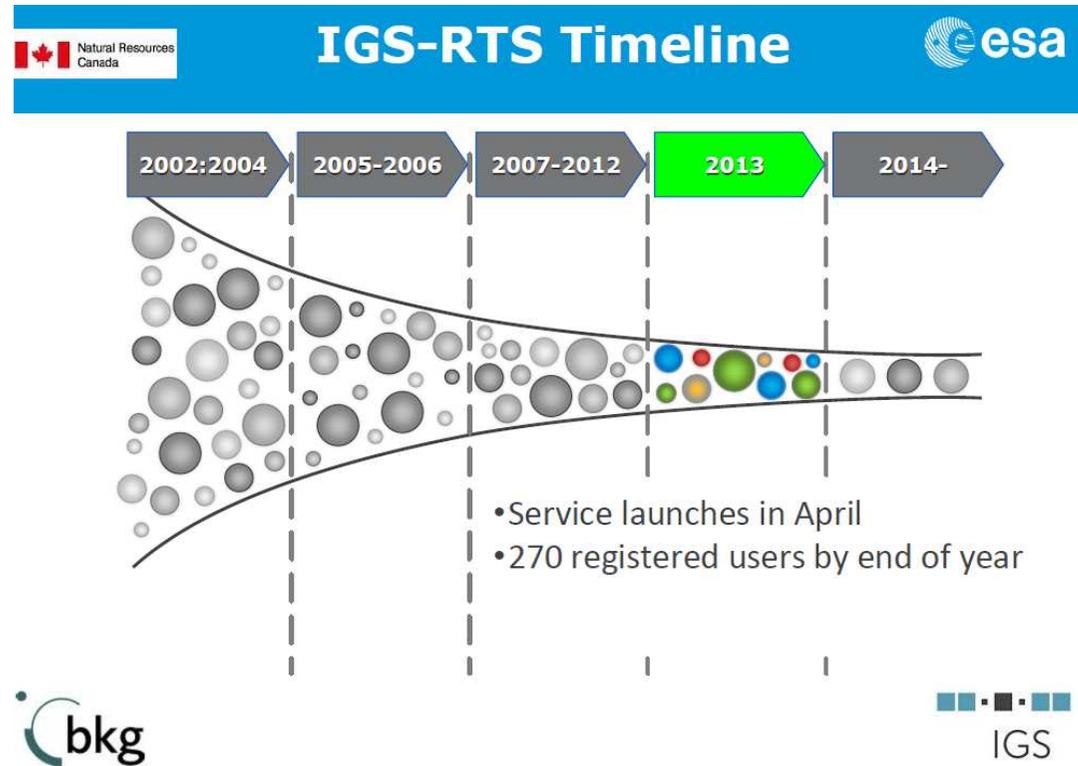
Station operations, Data Centers, Analysis Centers,
Combination Centers, Analysis Coordination, NTRIP caster
operation, ...



International Association of Geodesy



IGS Real Time Service



Development from creation of the Real-time working group to the launch of the service in 2013 and to the performance in 2014/15. Chair Mark Caissy (NR Can), Co-Chair Loukis Agrotis, ESA/ESOC, protagonist Georg Weber (BKG).

International Association of Geodesy

IGS Real-time Tracking Network



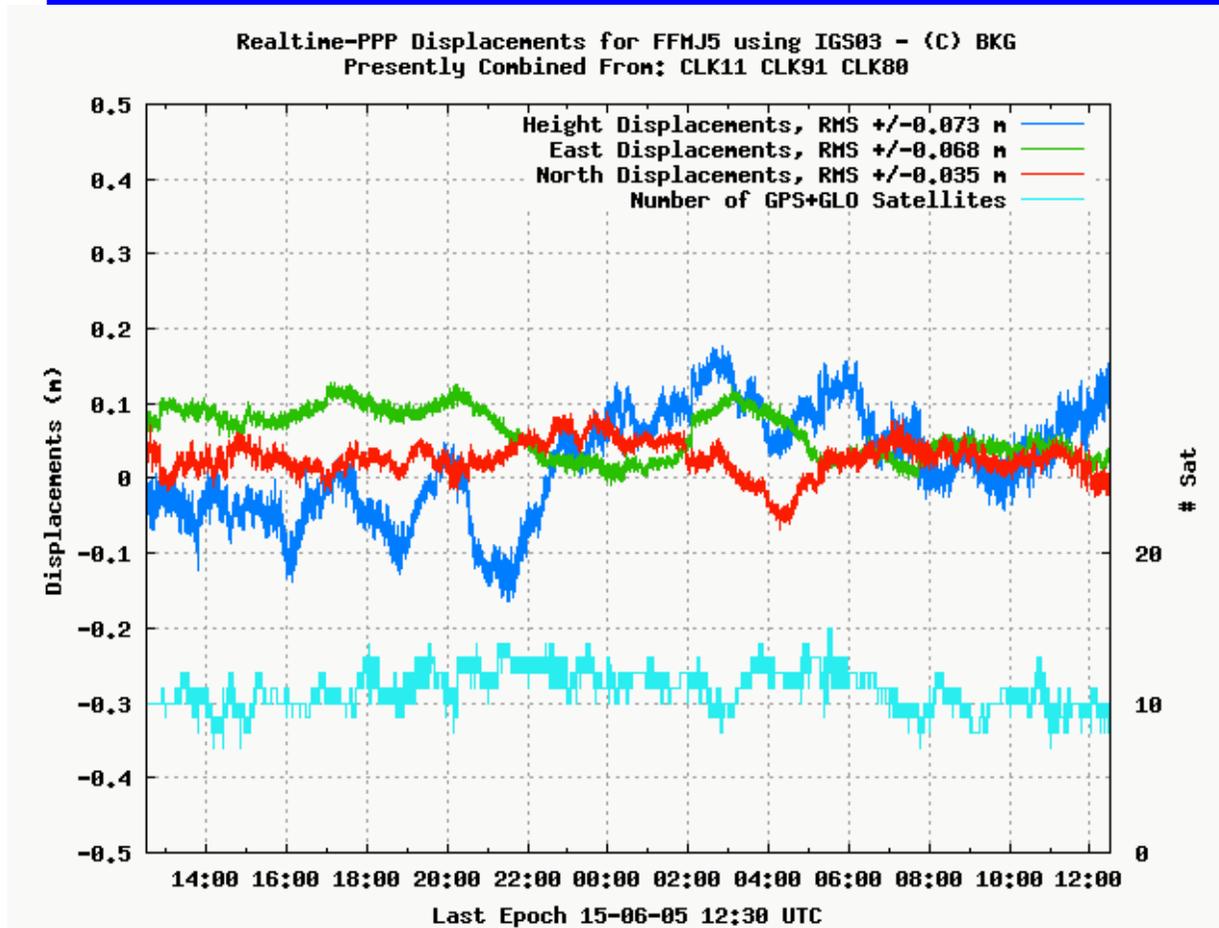
GMT 2014 Jul 22 18:38:26

150+ stations

International Association of Geodesy



IGS RTS Product Performance IGS03

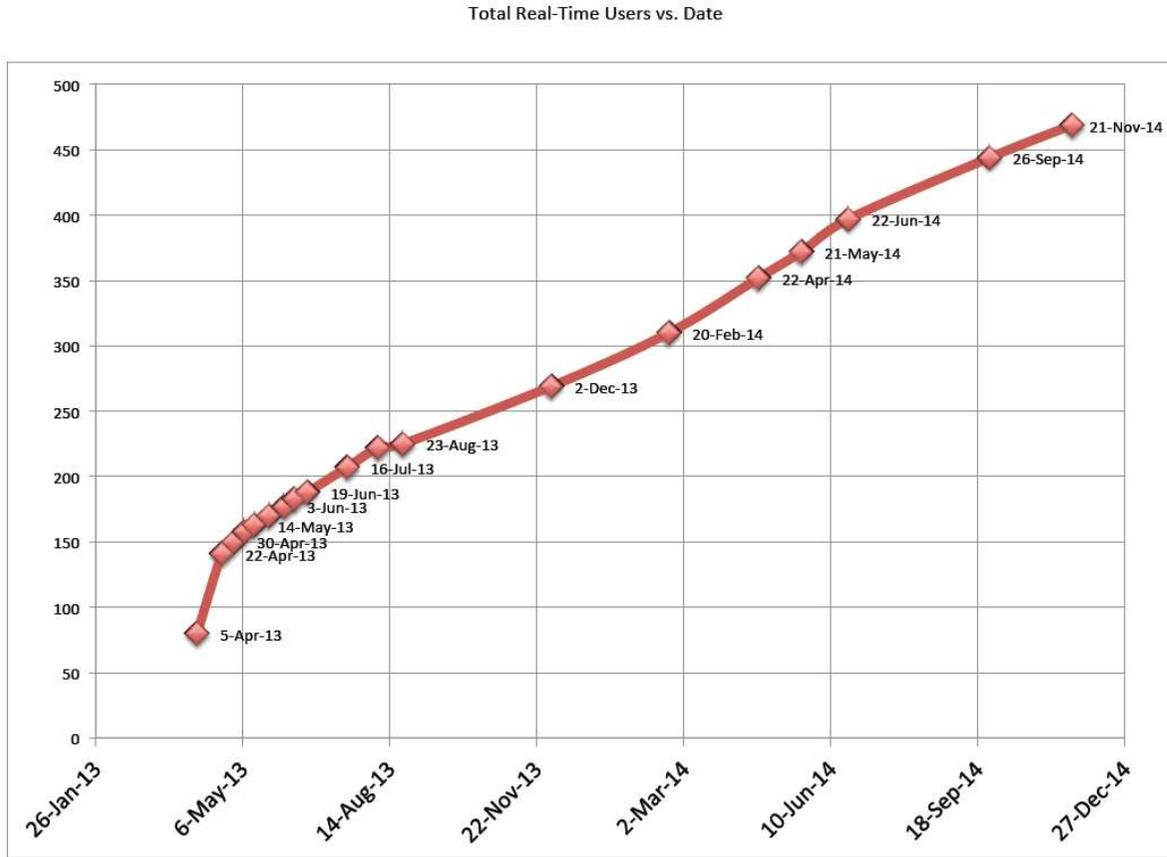


RMS
N ± 0.04 (m)
E ± 0.07 (m)
U ± 0.07 (m)

GPS & GLONASS sats



IGS RTS Users – currently > 500



IGS Real-Time User Statistics

11/21/14

International Association of Geodesy



IGS Ionosphere-related activities

The IGS operates the **Ionosphere Working Group** with Prof. Andrzej Krankowski from Poland as chair.

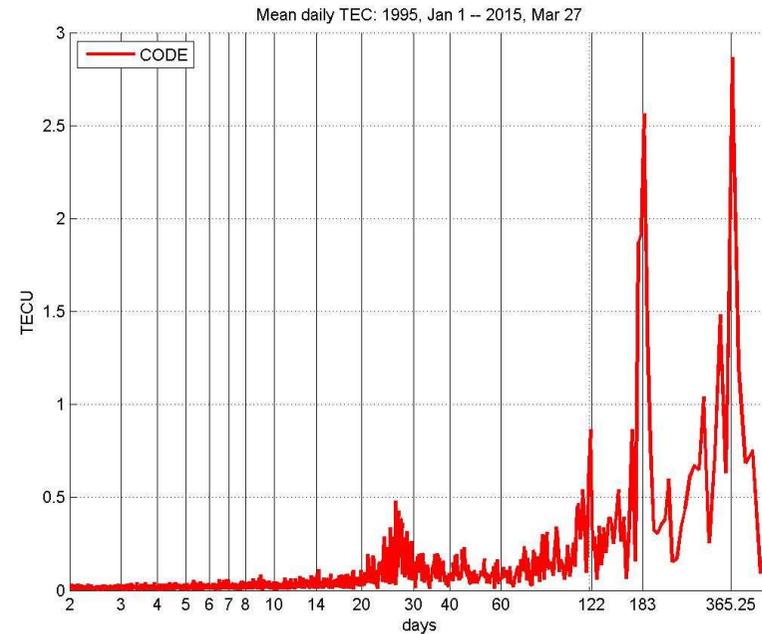
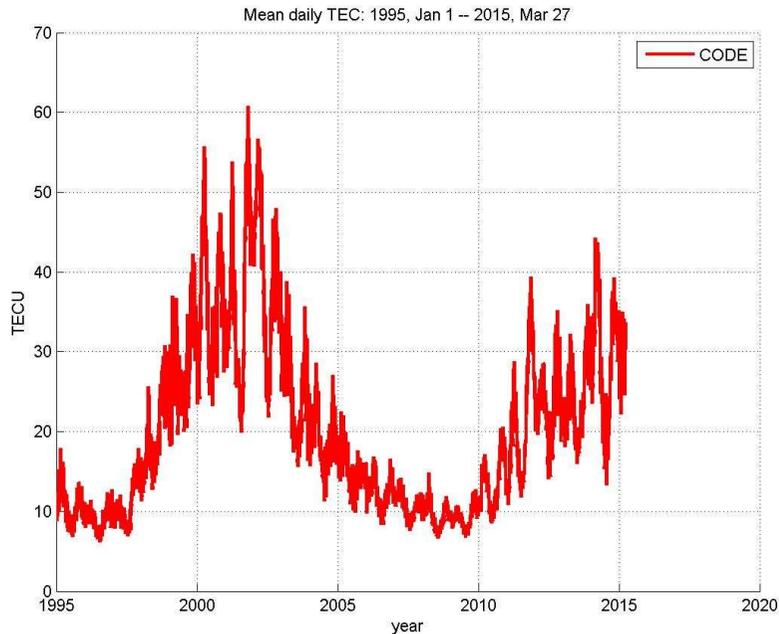
It generates the IGS Global Ionosphere Maps (GIMs) with a ...
... temporal & spatial resolution of **2 hours x 5 deg x 2.5 deg** (UT x long x lat).

It also generates **TEC fluctuation maps**, maps of Rate of TEC Index (**ROTI**) of the **arctic region** as a pilot project.

Both kinds of maps are based on the so-called single layer model, where it is assumed that all free electrons are contained in a layer of infinitesimal thickness at height $H=450\text{km}$.

Hundreds of IGS stations are contributing to the maps.

IGS Ionosphere-related activities

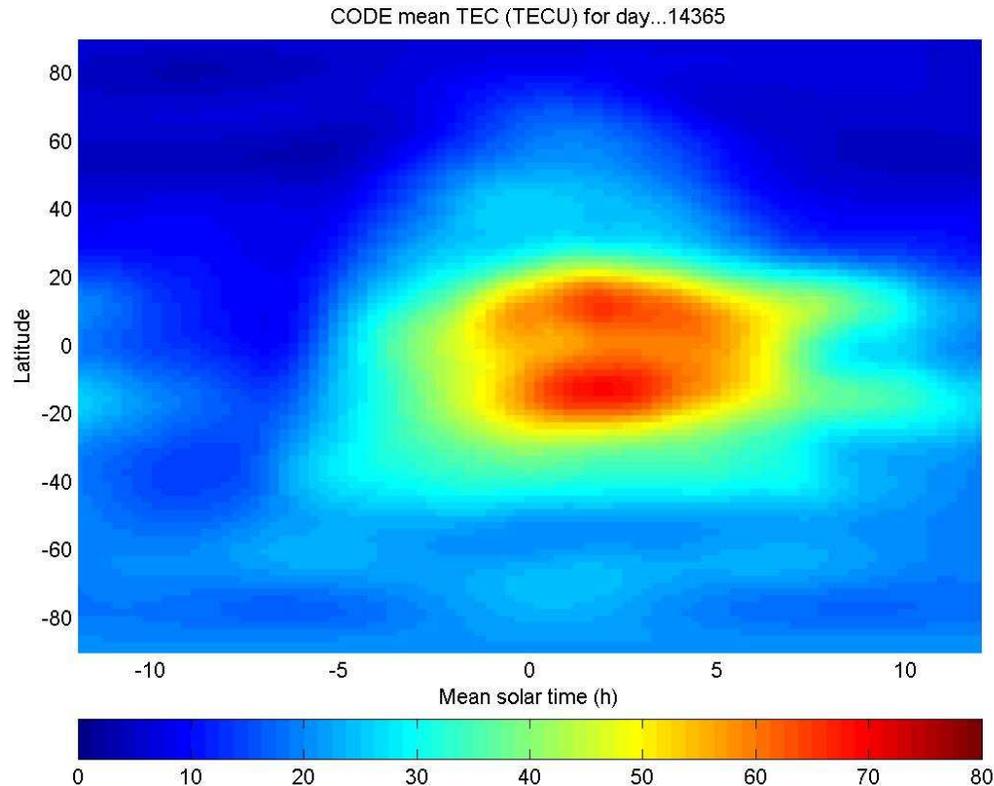


Mean daily ionosphere content since 1995 (left), associated spectrum (right) from CODE spherical harmonics model.

Main spectral lines (right): @ 27 days (rot of Sun), @ $365.25/i$, $i=1,2,3, \dots$, from orbital motion of Earth and Earth orientation in space (seasons).

International Association of Geodesy

IGS Ionosphere-related activities



**Day-averaged GIM of
New Year's Eve 2015**
**From CODE's 25 GIMs
based on a spherical
harmonics develop-
ment up to degree
and order 15.**

**Coordinate system:
geomagnetic /
equatorial, co-
rotating with Sun.**

**Units: TECU,
1 TECU = $1 \cdot 10^{16}$ e⁻/m².**

IGS Ionosphere-related activities

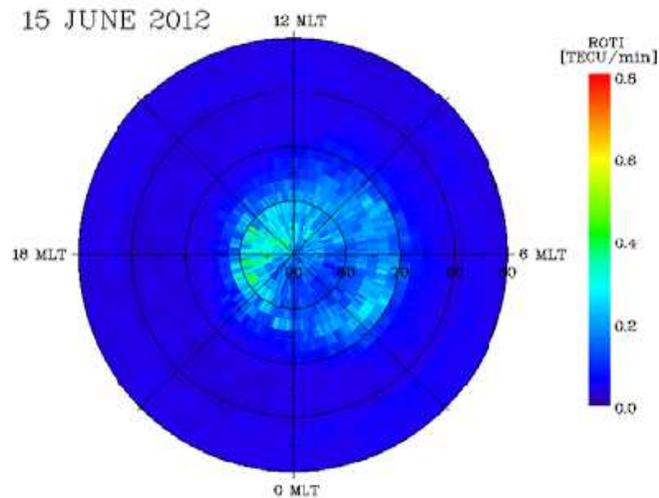


Fig. 3 The example of ROTI map for the geomagnetic quiet day.

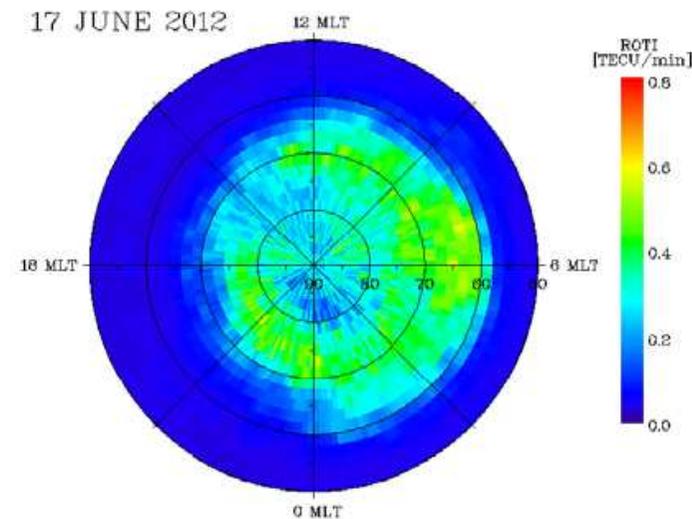
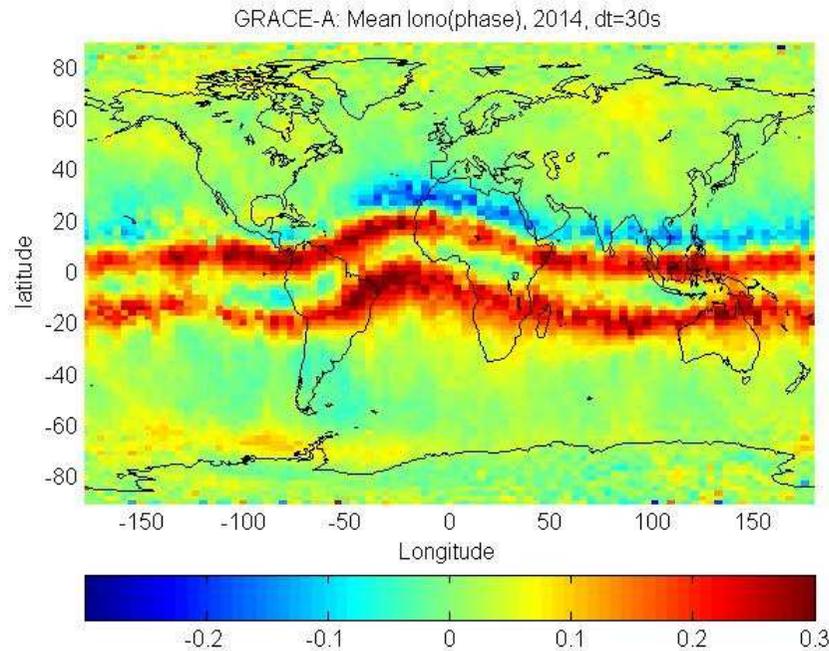


Fig. 4 The example of ROTI map for the geomagnetic disturbed day.

Rate of TEC in TECU/min due to scintillation on a calm (left) and “not so calm” day.

from Krankowski et al. (2013) “IGS Ionosphere Working Group Report, December 2013”.

IGS Ionosphere-related activities



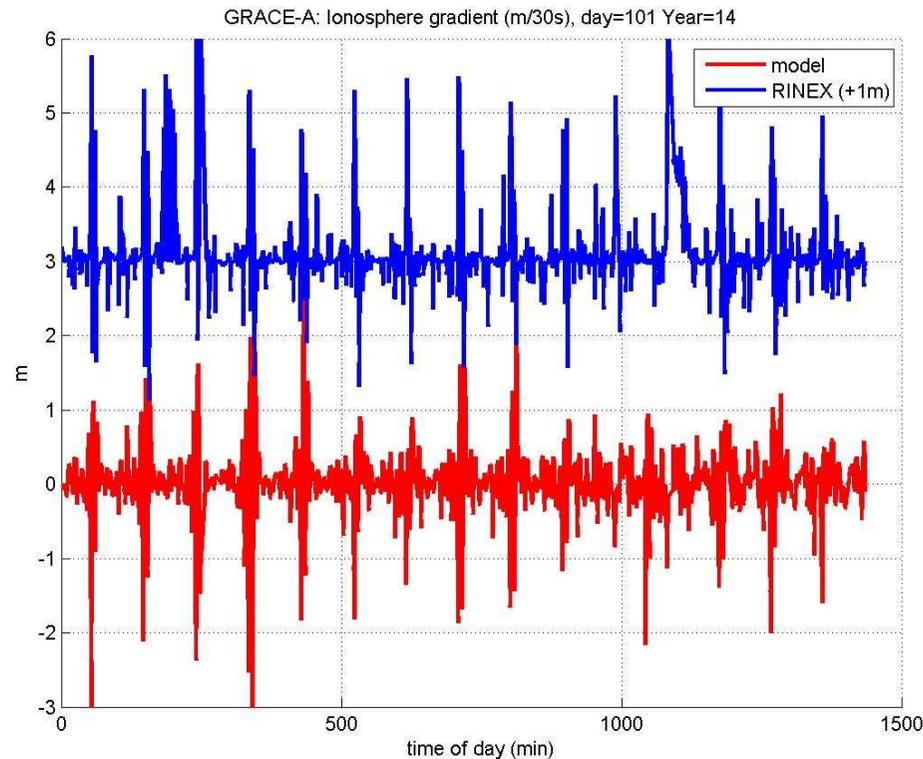
Ionosphere gradients derived from GRACE-A in first half of 2014. (TECUs/30s)

Low Earth Orbiters (LEOs) scan “in essence” a meridian of the Earth in about 90 minutes.

By combining data from several months, one obtains fantastic complementary information to the IGS GIMs concerning the Earth’s ionosphere – also of scintillation effects.

International Association of Geodesy

Combine IGS and LEO-derived GIMs



Ionosphere gradient from 2h-GIMs (red) and from GRACE geometry-free LC (plain difference of L1 and L2 phases in m).

- GIMs are very useful for LEO data analysis
- LEOs could/should contribute to IGS GIMs

LEOs scan one complete Earth meridian in 90 minutes at different altitudes!

From GRACE RINEX File of Day 100 of year 2014