GNSS for Science: Today and in Future

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Panel of Experts, ICG-10

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Content

- Science enabled by GNSS
- The International GNSS Service (IGS)
- IGS, IAG, ICG, etc.
- GNSS Research today
- Perspectives on science with GNSS
  - today
  - future

Science enabled by GNSS

Classic research / application fields centered around the magic formula "PNT", positioning, navigation and timing

Atmospheric research

- Troposphere monitoring, e.g., by limb sounding
- Ionosphere mapping & characterization of stochastic properties

Gravity field determination using spaceborne GNSS on LEOs

Geodynamics (polar motion, nutation, length of day)

Global monitoring of all available GNSS satellites using global network of permanent GNSS receivers is mandatory.

IAG, IGS, GGOS, GIAC and ICG

IAG, the **International Association of Geodesy** is a scientific organization in the field of geodesy promoting scientific cooperation and research […] on a global scale […].

IGS, the **International GNSS Service**, is a scientific service of the IAG, enabling highest-accuracy applications, including scientific applications.

IERS is the **International Earth Rotation and Reference System Service** (of IUGG and IAU) using the IGS products to generate technique-overarching geodetic & astronomical products.

The IGS is an associate member of the **ICG**, the **International Committee on Global Navigation Satellite Systems**.

The IGS

The International GNSS Service (IGS) is a voluntary federation of more than 200 worldwide agencies that pool resources to generate precise GNSS products.

The IGS makes its products available – free of charge – for science and the wider GNSS user community.

The IGS: current achievements

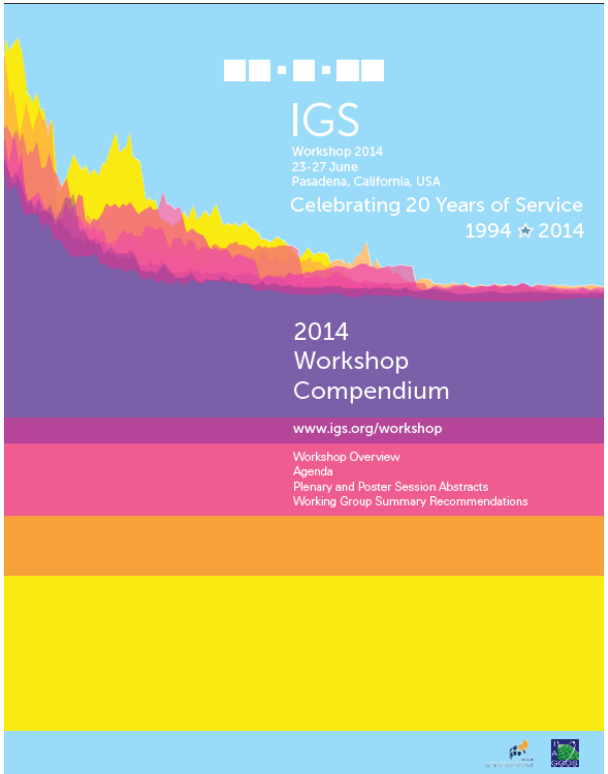
The IGS provides ephemerides (accurate to 2-4 cm) for 32 GPS satellites and for 24 GLONASS satellites (accurate to 5-8 cm), and other GNSS being deployed, i.e., for all currently active GNSS satellites.

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.

IGS products are accurate, reliable and validated. Combined products are formed by Coordinators and made publicly available in a timely manner.

IGS Workshop 2014: 20th Anniversary



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!

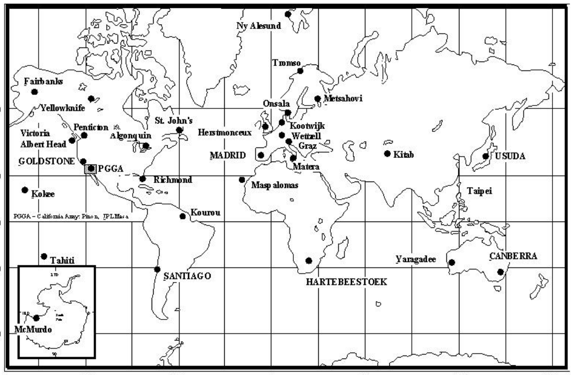
Ruth E Neilan

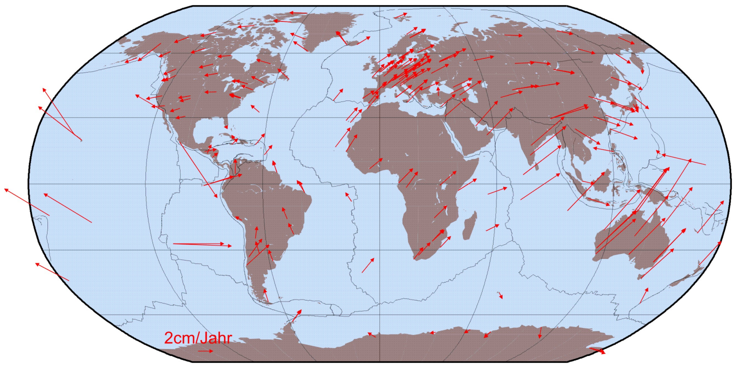
Ruth Neilan
IGS Central Bureau Director
Head of the Local Organizing Committee

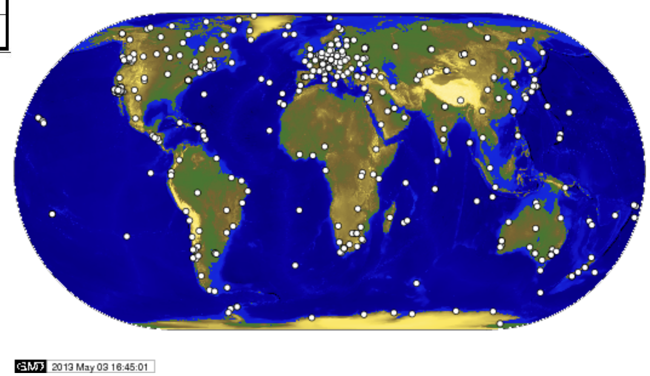
http://kb.igs.org/hc/en-us/articles/2048 Compendium. The IGS is regularly questioning and improving its performance and products. Next WS in 2016 in Australia.

The IGS: the network

Station Locations for the IGS Pilot Campaign, 1992







Monitor station positions & motion in „real time“ → contribution to ITRF

IGS Network in 2015

In 1992 the IGS network consisted of about 20 geodetic receivers, 400+ receivers are active and their data retrievable today.

UN-GGRF & resolution of reference frames

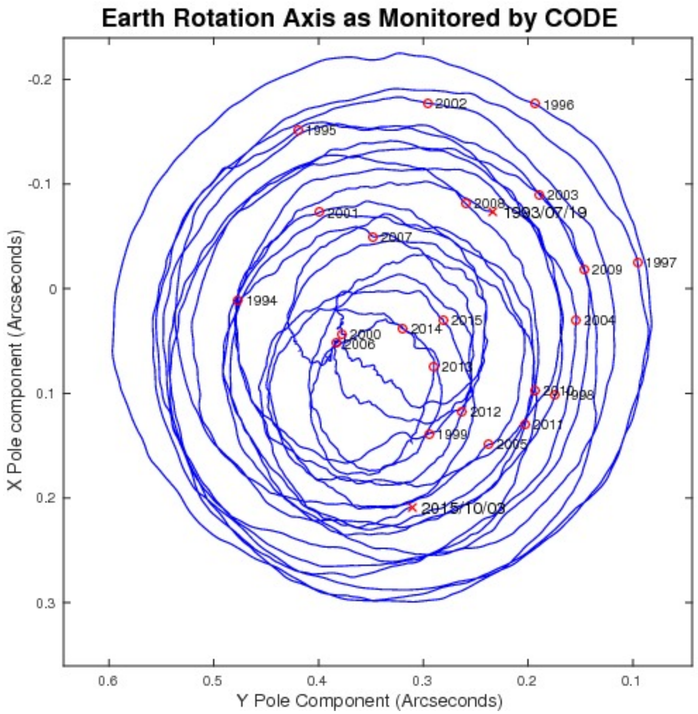
UN-GGRF (UN-Global Geodetic Reference Frames) is a working group of the UN Committee of Experts on Global Geospatial Information Management (UN GGIM).

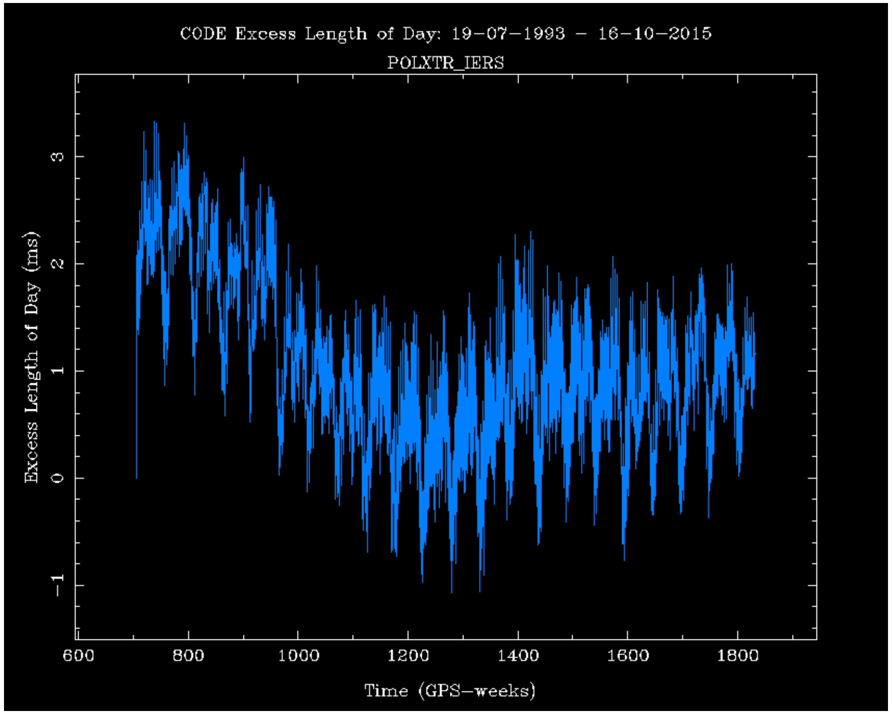
Its members are to a large extent members of the aforementioned IAG entities.

On February 26, 2015, **the first UN resolution about global geodetic reference frames** was adopted.

→ The resolution is an amazing **example** of the **science-driven community and decision makers from politics**, in particular of the UN **working together** to the benefit of society.

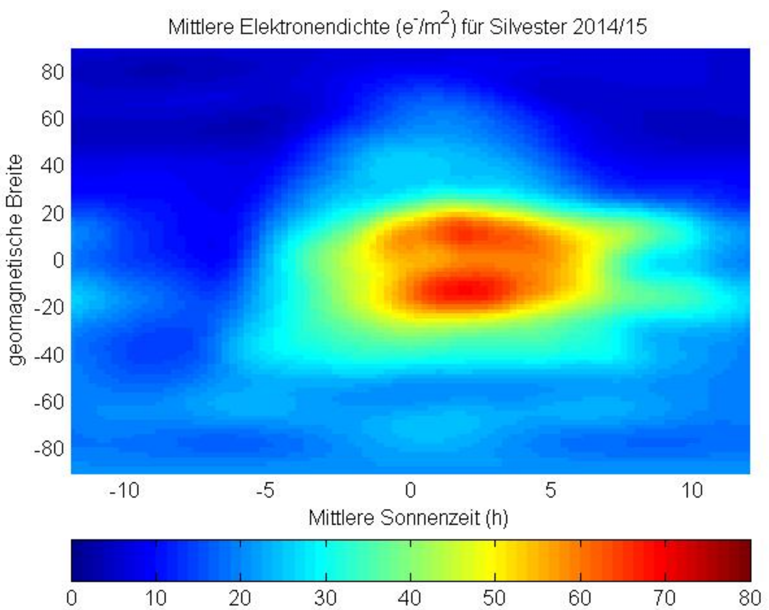
Earth Rotation

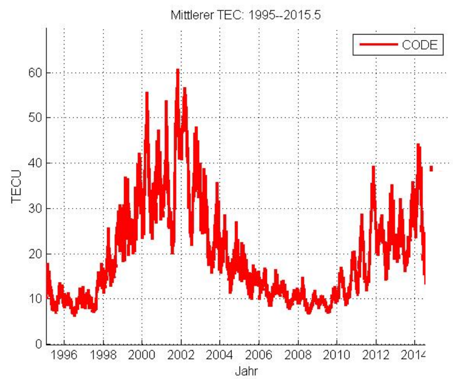


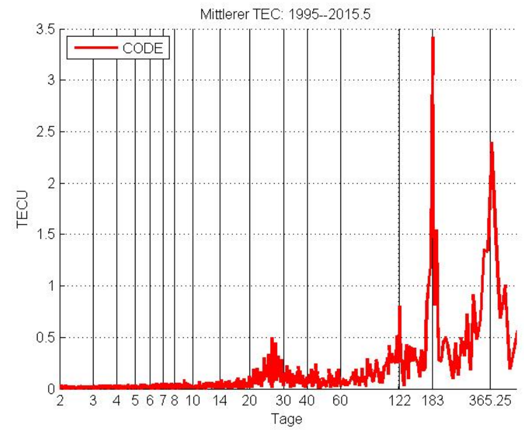


Left: Polar motion since 1993, Right: Excess Length of Day since 1993. Time resolution of IGS time series: 1 day. "millimetric" accuracy on Earth's surface. Current time resolution: 1 day.

The Earth’s Ionosphere

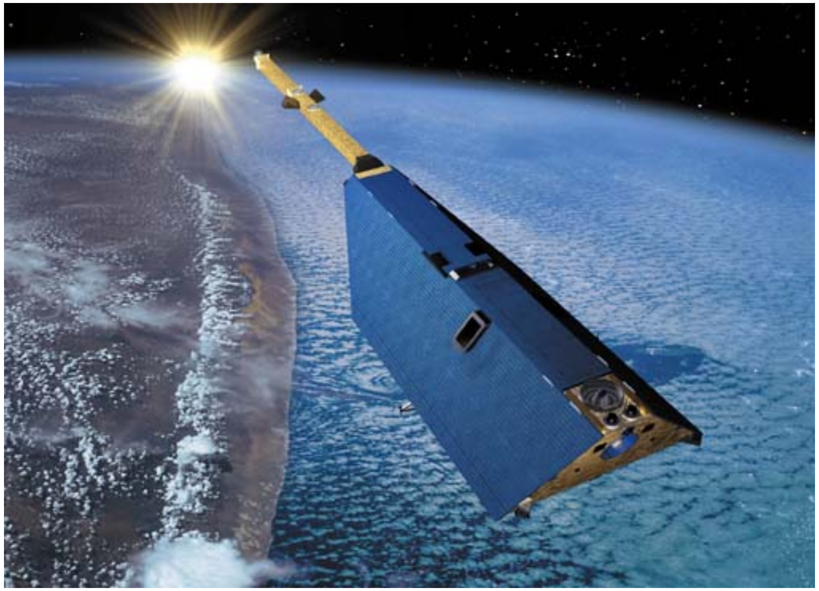


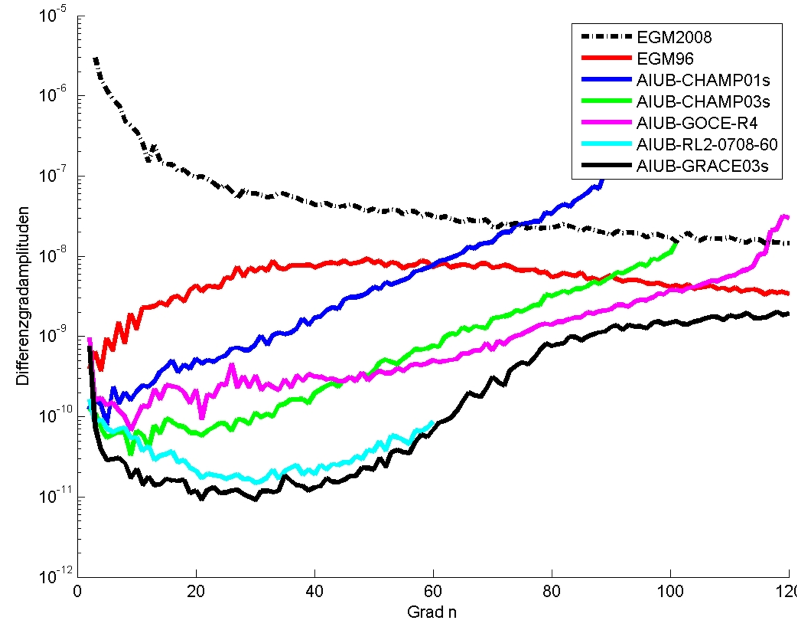




Left: Two-hour spapshot of the ionosphere Center: Mean TEC 1995. 2015 Right: Spectrum of daily mean TEC

Earth's Gravity Field





Left: CHAMP with GPS receiver

Right: Quality of CHAMP gravity field (green) much better than best gravity field available in 1996 (red)

Future in GNSS: the science perspctive

Until about 2007/08 GNSS was synonymous to GPS + minor contributions from other systems.

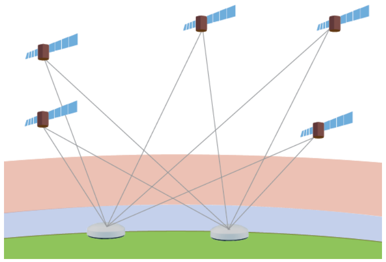
Today we have two fully operational systems, namely GPS and GLONASS, which are both capable of meeting the geodetic needs.

A combined analysis results in better products for science and the wider user community.

2018 there will be 3+ fully operational systems.

The future has already begun in the IGS with the MGEX (Muliti-GNSS Experiment)

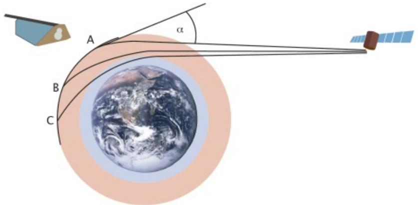
MGEX: Why Multi-GNSS?



More Satellites

- Improved PPP convergence
- More pierce points for atmospheric sounding
- Decorrelation of height, clock, troposphere

(G.Elgered)



Improved Signals

- Less multipath
- Increased robustness (scintillation, weak signals)

(G.Elgered/J.Wickert)

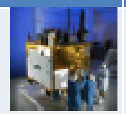
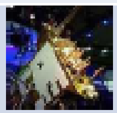
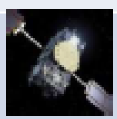
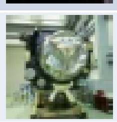
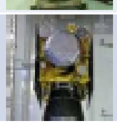
Stable clocks

- Improved Real-time PPP
- Orbit improvement / prediction

Diversity

- Different orbital periods and commensurabilities
- Decorrelation of estimated parameters (orbits, Earth rotation)

MGEX: Today‘s „System of Systems”

System	Blocks	Signals	Sats*)
GPS 	IIA IIR IIR-M IIF	L1 C/A, L1/L2 P(Y) L1 C/A, L1/L2 P(Y) +L2C +L5	3 12 7 9
GLONASS 	M M+ K1	L1/L2 C/A+P L1/L2 C/A+P, L3 (CDMA) L1/L2 C/A+P, L3 (CDMA)	23 1 (2)
BeiDou 	GEO IGSO MEO 3rd generation	B1, B2, B3 B1, B2, B3 B1, B2, B3 (B1,B3)	5 5 3 (1)
Galileo 	IOV FOC	E1, (E6), E5a/b/ab E1, (E6), E5a/b/ab	3+(1) (2)+(2)
QZSS 	IGSO	L1 C/A, L1C, SAIF L2C, E6 LEX, L5	1
IRNSS 	IGSO	L5, S	4

*) Status June 2015; brackets indicate satellites not declared healthy/operational

Modeling GNSS Orbits

- Lageos (LAser GEodetic Satellite); spherical, diameter 60cm, mass 405kg
- GNSS satellite: Body 2 x 2 x 2 m^3, "wings" 20 x 2 m^2, mass 500-1000kg
- From science perspective: GNSS satellites are too complex, radiation pressure difficult to model

Modeling GNSS Orbits

Ferraris are built to minimize non-gravitational forces, trucks not really (only "to some extent").

From the p.o.v. of orbitography the Lageos is a Ferrari, the GNSS satellite is a truck.

Future GNSS/IGS-related research topics

Consolidated Multi-GNSS products

Earth-rotation parameters with higher than daily time resolution …

Contribute with GNSS to nutation

Time varying gravity field (lowest harmonics)

Stochastic characterization of ionosphere (currently pilot phase)

Improve LEO orbit determination based on GNSS (not only GPS)

Ionosphere research using LEO observations

...

Wishes …

All GNSS satellites equipped with Laser Reflectors

Information needed from all GNSS: The IGS is only capable of generating integrated and highest quality GNSS products, provided the information on

- satellite properties (mass, surface, reflectivities),
- Attitude,
- Satellite clock properties,

is available from system providers. ICG is the ideal platform for that purpose.

IGS acknowledged by PNT, ICG as provider for highest accuracy GNSS products.

IGS-internal:

Include LEO GNSS receivers for product generation.

Acknowledgement

Slides on MGEX from Oliver Montenbruck's presentation on the occasion of the 15th PNT Advisory Board Meeting

MGEX Products

Post-processed

Precise orbits and clocks

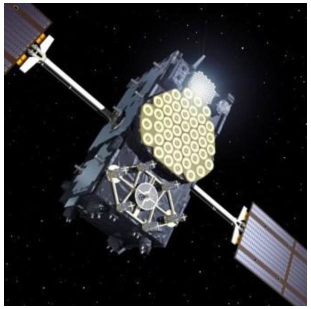
Broadcast ephemerides

Differential code biases

Real-time

Broadcast ephemerides

Orbit and clock corrections (Galileo)



UN Resolution February, 2015

2015
TIME FOR
GLOBAL ACTION
FOR PEOPLE AND PLANET

PRESS RELEASE

UN General Assembly urges sharing of geospatial data to benefit people and planet

26 February, New York – The science that supports the precise pinpointing of people and places should be shared more widely, according to the United Nations General Assembly as it adopted its first resolution recognizing the importance of a globally-coordinated approach to geodesy – the discipline focused on accurately measuring the shape, rotation and gravitational field of planet Earth.

Geodesy plays an increasing role in people's lives, from finding disaster victims to finding directions using a smart phone.