

The IGS-MGEX Experiment

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Navigation, and Timing (PNT) Advisory Board**

Omni Shoreham Hotel

2500 Calvert Street NW

Washington DC

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Topics

- **GPS, GLONASS, GALILEO, BeiDou, QZSS: Status December 2013**
- **IGS = International *GNSS* Service**
- **The MGEX Experiment**

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GPS, GLONASS, Galileo

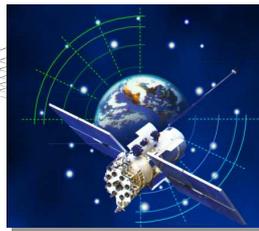
GPS: USA , 32 satellites in 6 planes
GLONASS: 24 satellites in 3 planes

All GLONASS and Galileo
satellites are equipped with
SLR reflectors

Galileo: 4 IOV-satellites launched in 2011
& 2012



GPS



GLONASS



Galileo

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BeiDou and QZSS

BeiDou (Chinese System) shall consist of

- 27 Mean Earth Orbiters (GPS-like)
- 5 geostationary satellites (GEO, GSO)
- 5 geosynchronous satellites (inclination of 55 deg) (IGSO)
- By end of 2012 5 GEO, 4 MEO, and 5 IGSOs were active

QZSS (Japanese System)

- 3 geosynchronous satellites/orbits
- HEOs (Highly Inclined elliptical orbits; $i=43$ deg, $e=0.075$)
- Currently one (QZS1) active

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GPS, GLONASS, Galileo, BeiDou, QZSS

System	Revolution Period	Inclination	# Orbital Planes
GPS	11 ^h 58 ^m	55 deg	6
GLONASS	11 ^h 16 ^m	65 deg	3
Galileo	14 ^h 05 ^m	55 deg	3
BeiDou	12 ^h 53 ^m	55 deg	3
QZSS	23 ^h 56 ^m	43 deg	3

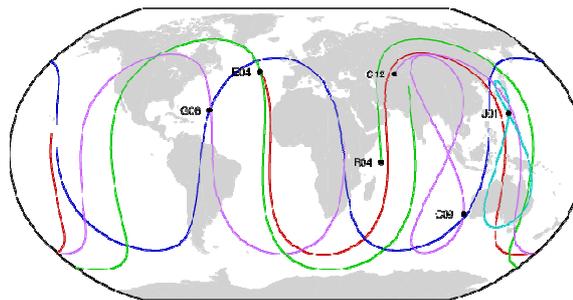
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GPS, GLONASS, Galileo, BeiDou, QZSS



Daily Groundtracks of **GPS**, **GLONASS**, **Galileo**, **BeiDou**, **QZSS** (geosynchronous, GPS augmentation).

(GPS, QZSS), GLONASS, Galileo have 1-day, 8-days, 10-days repeat cycles. BeiDou MEOs one of 7 days.

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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 providing continuity and leadership.

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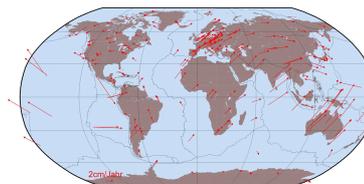
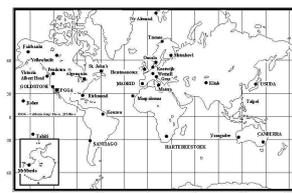


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The IGS

Station Locations for the IGS Pilot Campaign, 1992



Monitor station motion in „real time“



IGS Network in May 2013

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

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IGS-MGEX: Preparing the Ground for Multi-Constellation GNSS Science

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(*) Chair of IGS/MGEX Working Group

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**4th International Colloquium
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(December 4-6, 2013, in Prague, Czech Republic)**

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The International GNSS Service is ...

- ... the premier source of the highest-quality GNSS data, products, and related standards and conventions
- ... in support of many applications that benefit the scientific community and society
- ... a Service of the International Association of Geodesy (IAG) founded in 1994
- ... operational since more than 20 years
- ... a federation of more than 200 institutions and organizations worldwide
- ... following an open data policy
- ... open to everybody to participate

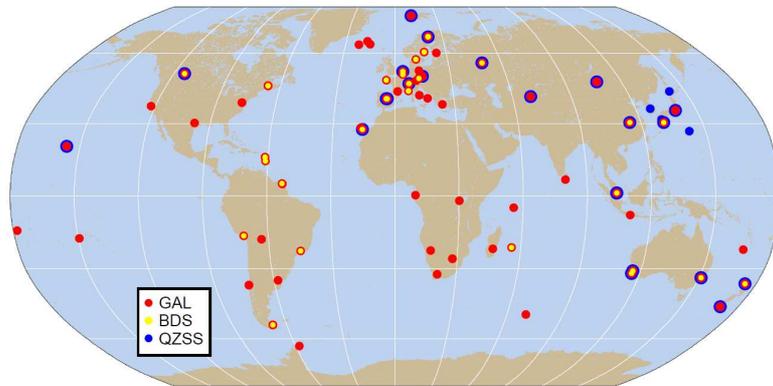
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The IGS MGEX Network



~90 Stations (Sep. 2013)

<ftp://cddis.gsfc.nasa.gov/pub/gps/data/campaign/mgex/>
<http://mgex.igs-ip.net/>

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IGS MGEX Equipment



- heterogeneous equipment environment
- many combinations
- cross-validation of equipment performance
- high robustness
- open to new equipment

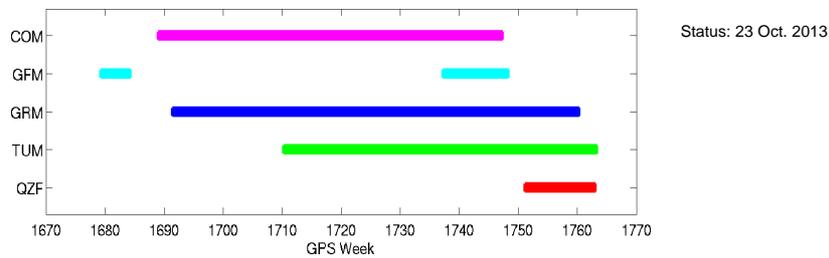
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MGEX Product Availability



Institution	Abb.	Systems
CNES/CLS, France	grm	GAL
CODE, Switzerland	com	GPS+GLO+GAL
GFZ, Germany	gfm	GPS+GAL
TUM, Germany	tum	GAL+QZS
JAXA, Japan	qzf	QZS

Products available at <ftp://cddis.gsfc.nasa.gov/pub/gps/products/mgex/>

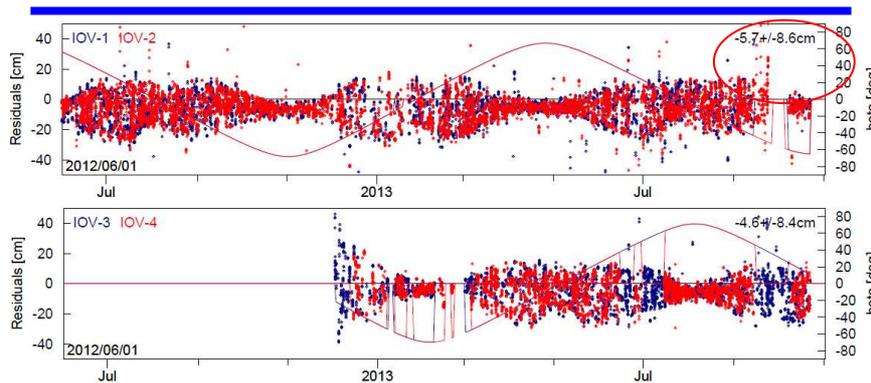
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Galileo-IOV



Combined CODE+TUM products for ~ 1.5 years

1/rev radial orbit errors with up to +/- 20 cm

Amplitude varies with Sun-angle above orbital plane (β -angle)

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Constellation Broadcast Messages

„All-in-one“ multi-GNSS broadcast ephemeris file formed from concatenated broadcast information of all constellations

Covers all constellations (GPS+GLO+GAL+BDS+QZSS+SBAS) except IRNSS

Presently approx. 85 satellites

Product available from Jan 2013 onwards

```
3.02      NAVIGATION DATA      M (Mixed)      RINEX VERSION / TYPE
BCEmerge      congo      20130610 034603 GMT PGM / RUN BY / DATE
Merged GPS/GLO/GAL/BDS/QZS/SBAS navigation file      COMMENT
based on CONGO and MGEX tracking data      COMMENT
DLR: O. Montenbruck; TUM: P. Steigenberger      COMMENT
GAUT  2.7939677238e-09-8.881784197e-16 428400 1743 1743 0 TIME SYSTEM CORR
GLGP -3.7439167500e-07 0.000000000e+00 518400 1743 1743 0 TIME SYSTEM CORR
GLUT -2.0954757929e-07 0.000000000e+00 518400 1743 1743 0 TIME SYSTEM CORR
GPGA -1.4551915228e-09 4.440892099e-15 518400 1743 1743 0 TIME SYSTEM CORR
GPUT  0.000000000e+00-2.664535259e-15 233472 1744 1744 0 TIME SYSTEM CORR
QZUT -3.9290171117e-09 1.243449788e-14 230400 1744 1744 0 TIME SYSTEM CORR
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Standardization Efforts

Continued interactions of MGWG with:

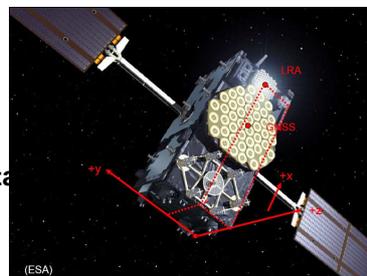
- GNSS system providers
- Equipment manufacturers
- Other IGS Working Groups (Ant WG, Bias WG, RT WG)

Recommendations, conventions and processing standards:

- Attitude models
- Antenna offsets and patterns

Data formats:

- Observations and navigation data (RINEX, RTCM3-MSM)
- Biases (SINEX?)
- Orbits



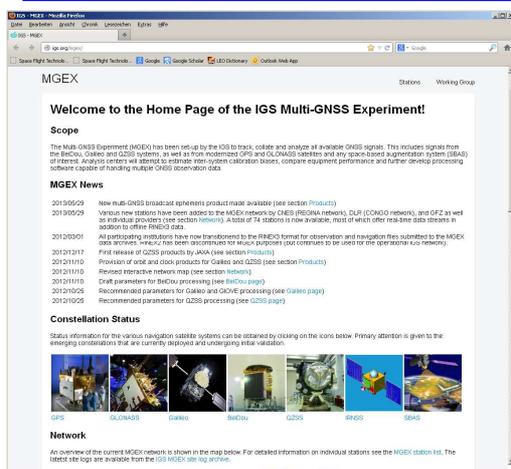
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IGS MGEX – <http://igs.org/mgex/>



- Central portal for MGEX related information
- Entry point for data and product servers

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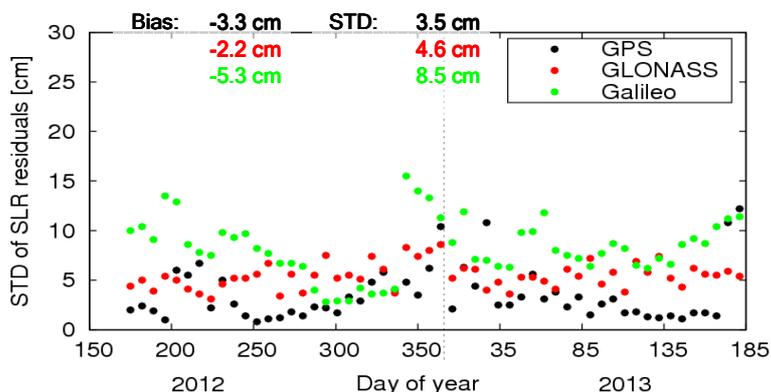


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Orbit validation: SLR residuals

STD of SLR residuals per week: GNSS-wise



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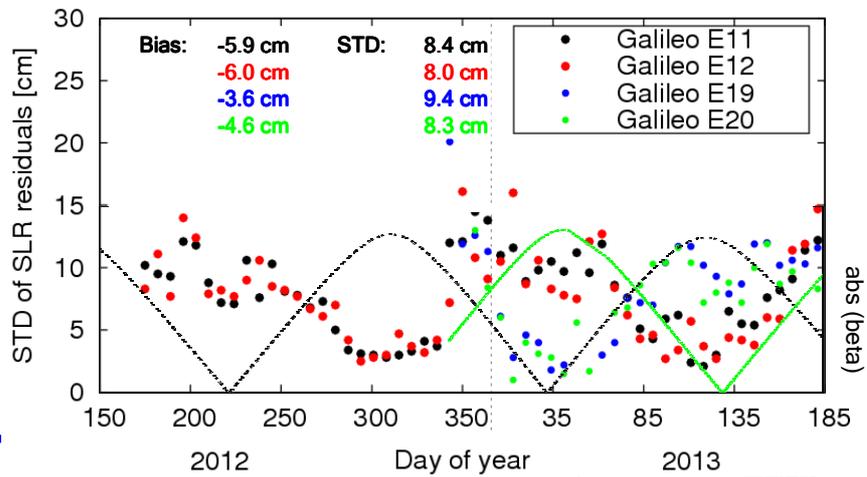


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Orbit validation: SLR residuals

STD of SLR residuals per week: correlation with beta angle



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PPP, kinematic mode (DOY 75 – 84)

From (Dach,2013) Difference to CODE MGEX network solution (threshold 10000 mm):

GPS+Galileo, GPS, GPS (4 SVs), Galileo

Station	North [mm]		East [mm]		Up [mm]	
	mean	STD	mean	STD	mean	STD
OUS2	3.0	33.0	-7.8	38.1	210.1	112.1
	2.5	38.6	-7.2	47.7	216.8	119.9
	-3132.4	2907.3	-3959.6	3819.2	5066.5	3375.5
	-104.6	1756.6	572.3	1036.7	-191.3	2251.3
RIO2	8.0	36.8	8.2	39.4	181.5	141.6
	7.8	43.9	12.2	47.5	185.7	149.0
	357.8	2034.4	63.0	901.1	557.2	4917.5
	-223.0	1283.7	-18.9	516.1	-549.8	1539.8
TASH	1.5	19.4	0.9	26.6	112.1	92.8
	1.1	21.6	-2.2	29.6	114.2	95.0
	2225.0	2677.2	-2679.8	3040.4	5133.4	3545.8
	-326.2	1229.5	270.9	741.1	-7.2	1393.7
ZIM3	3.0	12.5	3.5	16.5	30.0	54.2
	3.3	13.2	1.0	17.0	30.3	55.1
	265.0	2331.1	-360.0	1634.5	-1129.9	4364.2
	-112.2	690.3	13.8	369.2	246.7	944.6

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Summary

Establishment of Multi-GNSS Experiment beginning of 2012

Progressing steadily, currently network of more than 70 stations

Multi-equipment environment

SLR validation is of vital importance for many MGEX issues (GPS problem!)

Developing new products

Basis for monitoring of IF/IS biases, broadcast ephemerides, system time offsets, etc. is available

Targeting a multi-GNSS Pilot Service

MGEX needs

- Recruitment of additional analysis centers (quality control, orbit/clock products, bias products, etc.)
- GNSS stations in various areas (not just China)
- Spacecraft information (antennas, attitude) from system providers (Galileo and BeiDou, SBAS, IRNSS)

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Acknowledgements

Information concerning MGEX was taken – with permission – from a presentation by Montenbruck et al (2013), delivered at 4th International Colloquium Scientific and Fundamental Aspects of the Galileo Programme (December 4-6, 2013, in Prague, Czech Republic)

Information concerning SLR validation of MGEX products, concerning PPP, and concerning ground track with different systems taken from Prange et al (2013): The CODE MGEX orbit and clock solution. IAG Scientific Assembly 2013, Potsdam, Germany, September 01-06, 2013.

(http://www.bernese.unibe.ch/publist/2013/pres/IAG2013_MGEX_LP.pdf)

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