Making use of two fully deployed GNSS: The science perspective

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Sheraton Pentagon City Hotel

900 South Orme Street

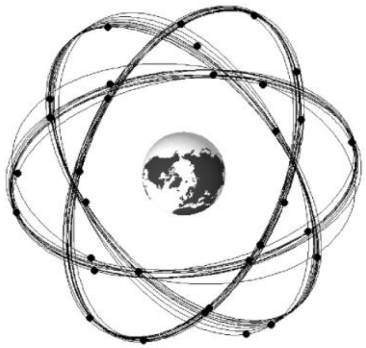
Arlington, VA 22204

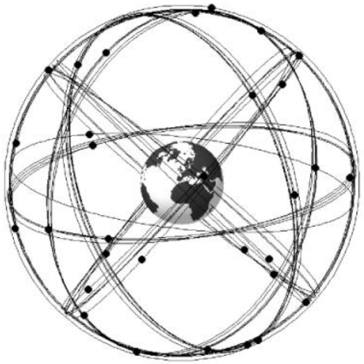
Topics

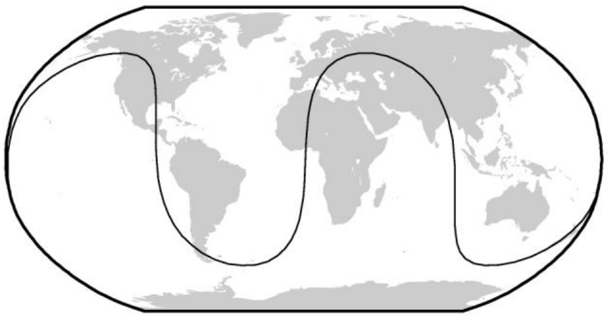
- **GPS, GLONASS, GALILEO: State August 2012**
- **GNSS-related activities in the IGS**
- **Are there substantial differences between different GNSS from the science perspective: A case study**
- **The case for SLR**
- **The case for accelerometry**

System Overview - GPS

- **32 operational satellites**
- **6 orbital planes**
- **Semi-major axis: 26'560 km**
- **Inclination: 55°**
- **Revolution period: 1/2 sidereal day (11h 58min)**
- **2 (3) frequencies, CDMA**

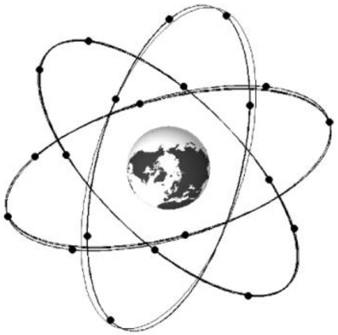


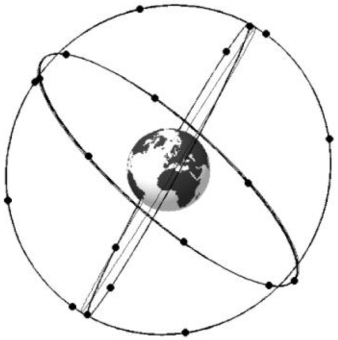


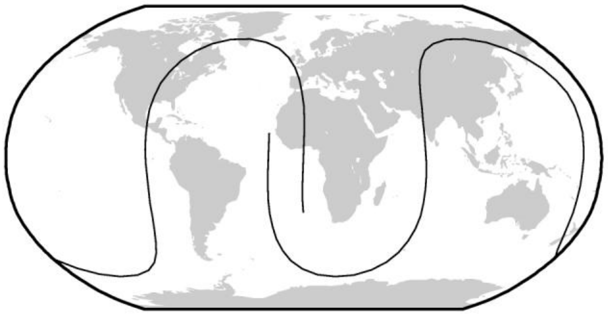


System Overview - GLONASS

- 24 operational satellites
- 3 orbital planes
- Semi-major axis: 25'510 km
- Inclination: 64.8°
- Revolution period: 8/17 sidereal days (11h 16min)
- 2 reference frequencies, FDMA

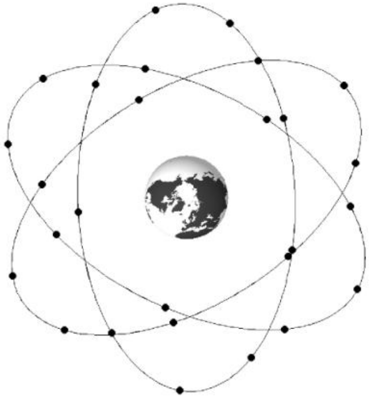


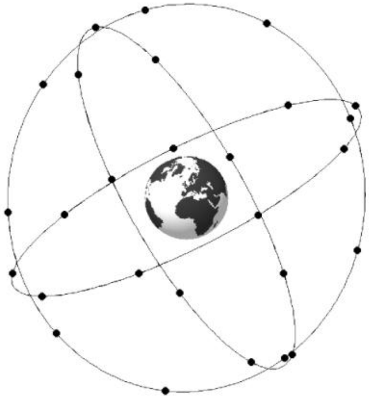


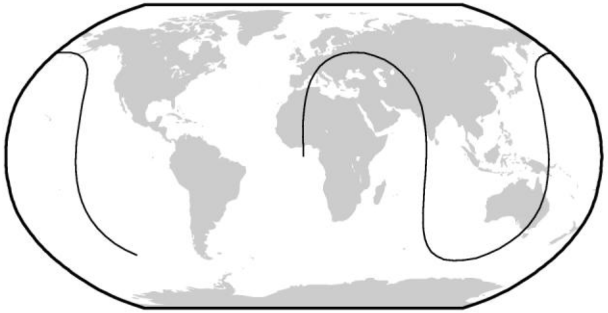


System Overview - Galileo

- 2 test satellites, 2 IOV satellites
- 3 orbital planes
- Semi-major axis: 29'600 km
- Inclination: 56°
- Revolution period: 10/17 sidereal days (14h 05min)
- 5 frequencies, CDMA







Why Multi-GNSS?

Benefits for the "normal user"

- Major improvement for real-time applications
- In particular in mid-latitude regions
- In difficult environment (restricted view of sky)

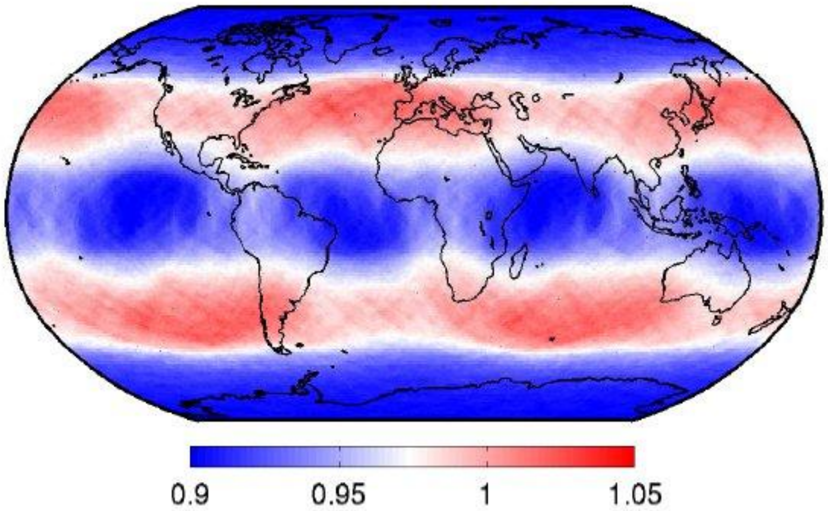
Benefits for scientific applications

- Additional signals and frequencies
- Different orbit characteristics of GNSS →
- Detection/separation of systematic error sources

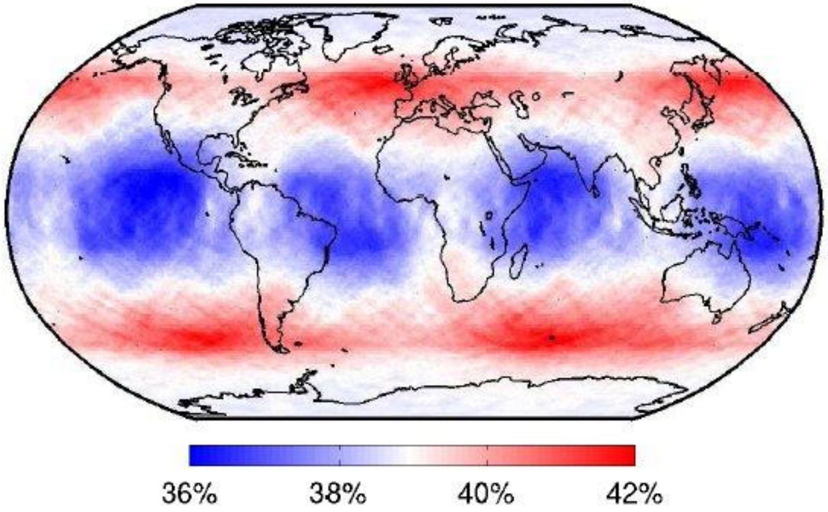
Why Multi-GNSS?

Position Dilution Of Precision (PDOP)

- ➢ **Quality indicator for navigation solution**
- ➢ **Smaller = better**



Mean daily PDOP
(GPS-only)



Mean PDOP improvement
(when adding GLONASS and Galileo)

The IGS and GLONASS

The IGS involvement in GLONASS was formally established in 1997 at the IAG Scientific Assembly in Rio de Janeiro.

Jim Slater of NIMA was one of the protagonists pushing the IGS to get involved.

The IGS GLONASS Pilot Service Project started in 2001.

The first operational GPS/GLONASS products became available in 2003.

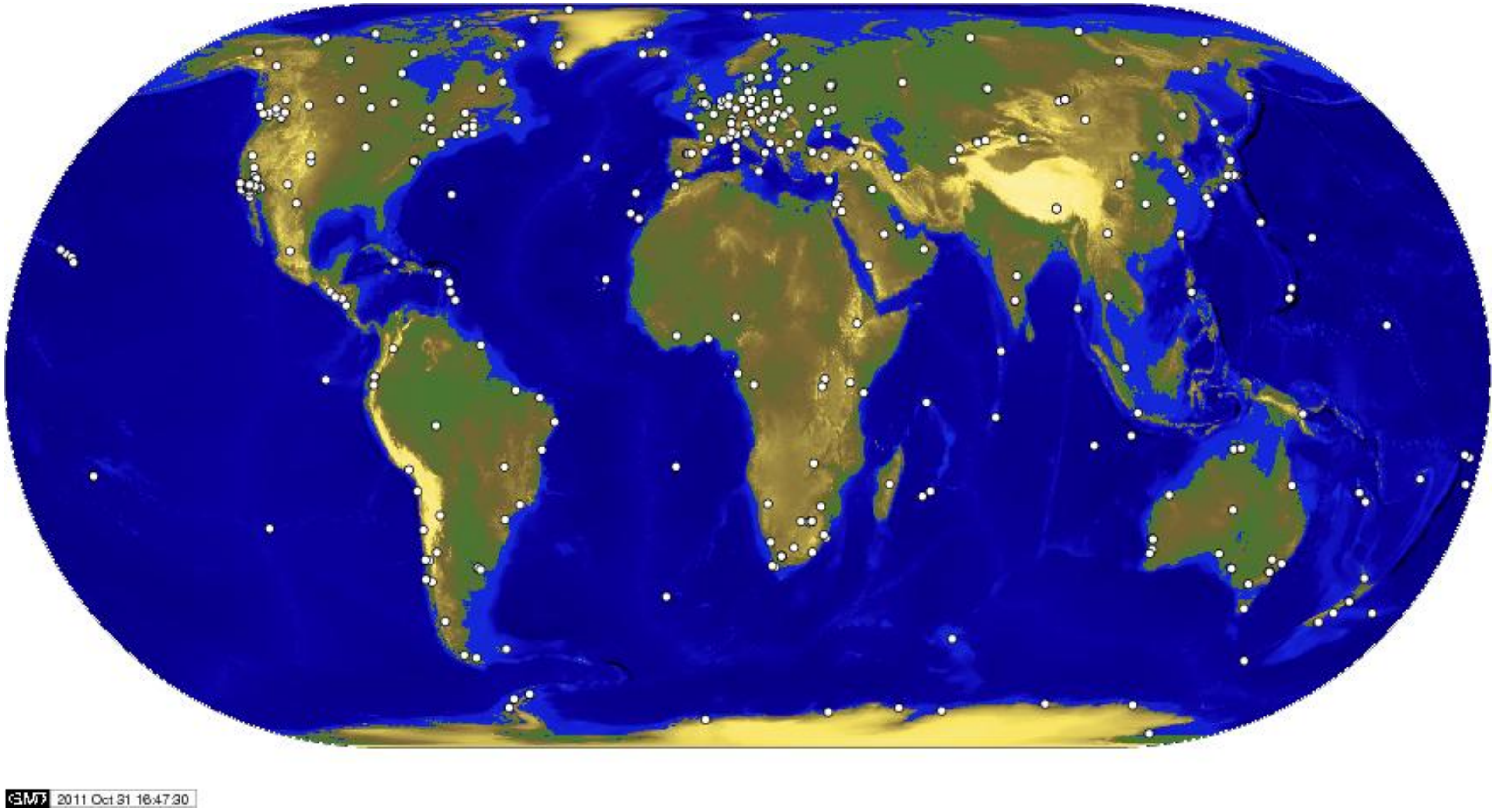
In 2005 the IGS was officially renamed as International GNSS Service (and no longer International GPS Service).

In 2011 the IGS launched the Call for Participation in the MGEX (Multi-GNSS Experiment) which will go beyond the GPS/GLONASS combination.

The key interest of the IGS is best possible combined GNSS product .

GGOS / IGS Tracking Network

400 active global tracking stations



International Association of Geodesy

http://igs.org

IGS Key Activities

Multi-GNSS Global Experiment – *IGS M-GEX*

- **operate an expanded network of new receivers capable of tracking new signals– Galileo, Compass, QZSS, and modernized GPS & GLONASS, in addition to available GPS & GLONASS**

Real-time **Pilot Project – transitioning to *Scientific Service after ten years* – to be announced as an open service in November 2012**

IGS contributions to the Global Geodetic Observing System – GGOS

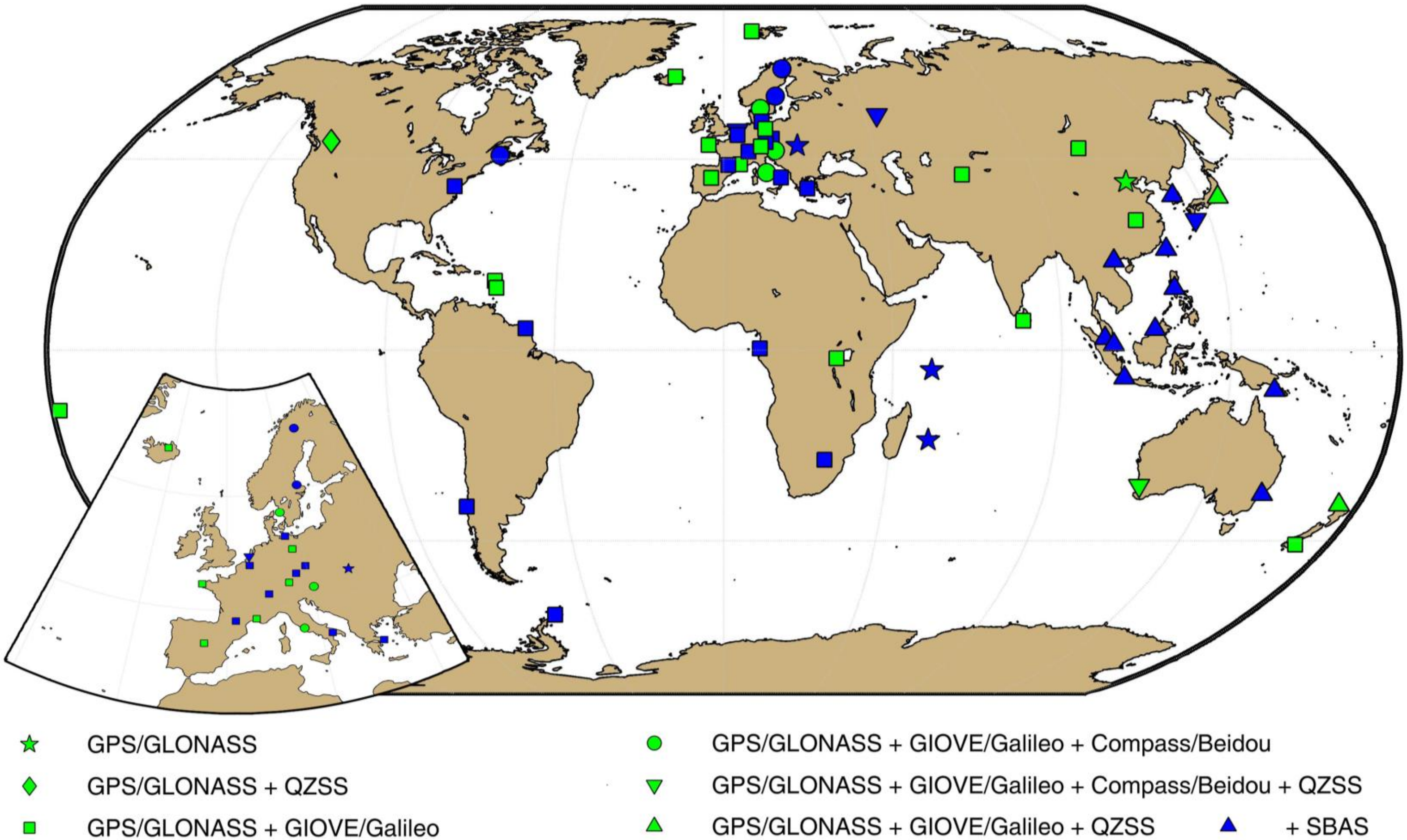
- **contributes to the densification of the International Terrestrial Reference Frame and provides access to most users**
- **Supports three themes of GGOS: Geohazard response and mitigation; and a Unified Height System, and Sea Level Change**

IGS is co-lead of International Committee on GNSS, Working Group on Reference Frame, Timing and Applications

- **Co-Chair of new ICG task –** International GNSS Monitoring and Assessment, **joint with Chairs from Japan and China**
- **Further developments afforded by of IGS M-GEX and upcoming open IGS Real-time Service**

IGS Multi-GNSS Experiment - Network

Network configuration July 2012



A Case Study

- Michael Meindl analyzed three (four) years of data of a globally distributed GNSS network of combined GPS & GLONASS receivers (in essence a sub-net of the IGS network)
- Separate GPS- and GLONASS- IGS-type solutions were produced as well as combined solutions.
- "IGS-type" implies that not only coordinates, but also satellite orbits, Earth rotation parameters, geocenter coordinates, etc. were determined.
- It was for the first time possible to generate IGS-type GLONASS-only solutions!

Design and Setup

Data from 2008–2010 were analyzed (data from 2011 were included later on)

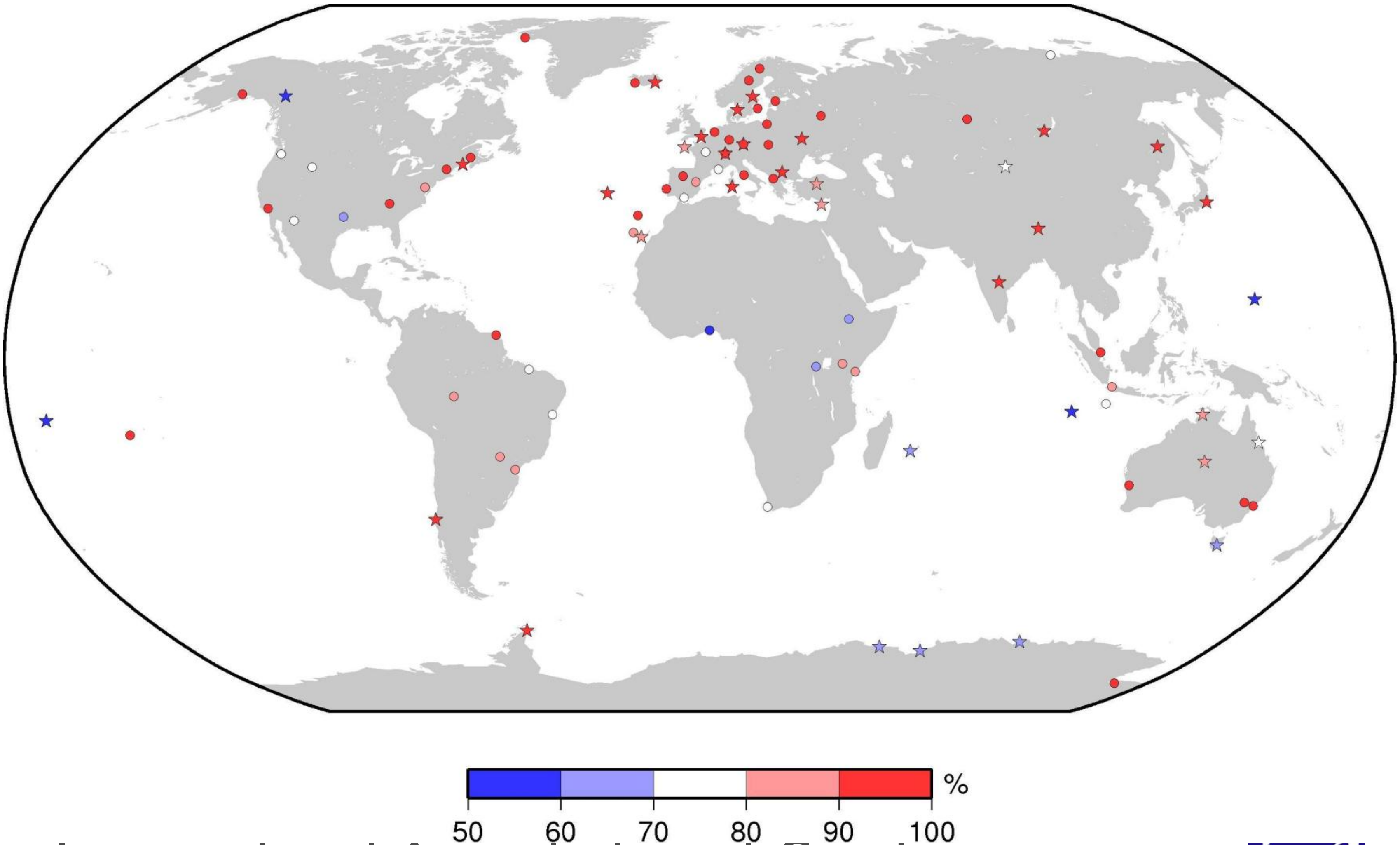
92 combined GPS/GLONASS stations were included

- globally distributed
- Availability at least 75% of the three years

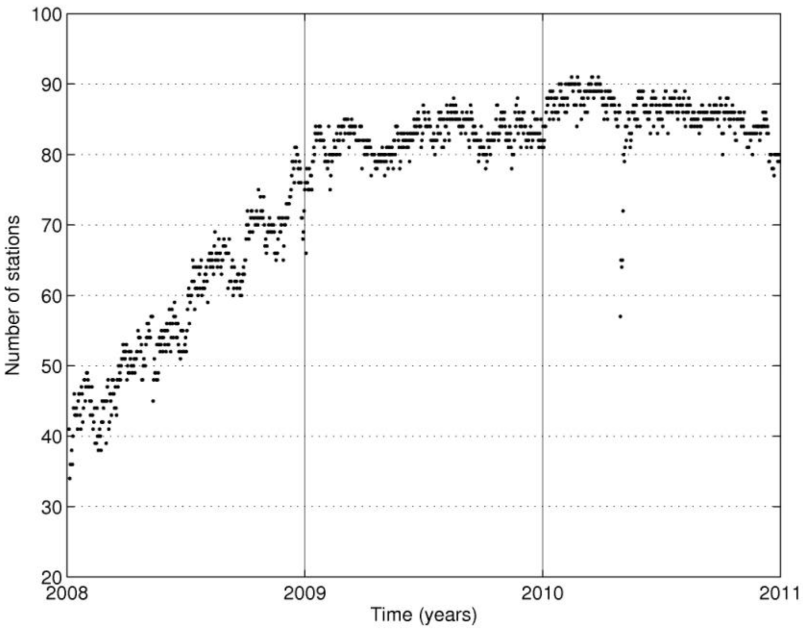
GPS and GLONASS contribute in a comparable way

- in particular concerning station selection

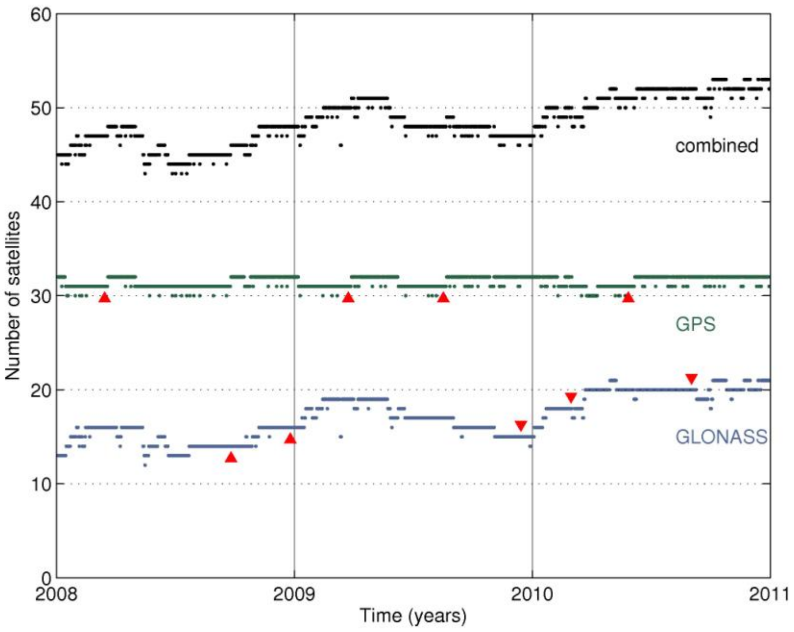
Design and Setup



Number of stations, Number of satellites



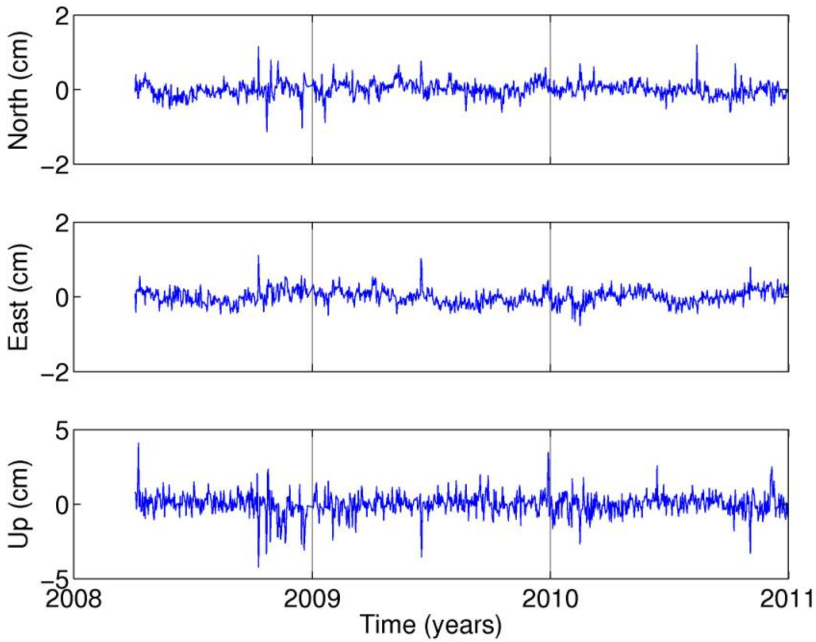
Number of stations



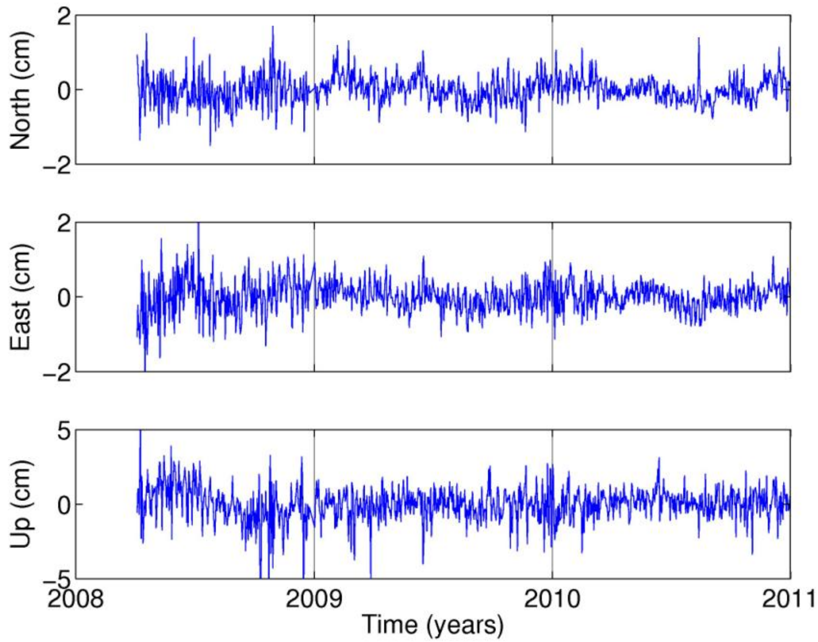
Number of satellites

Results – Station Coordinates

Repeatability: one station, batch length one day. GLONASS results are better than GPS 1994 results!



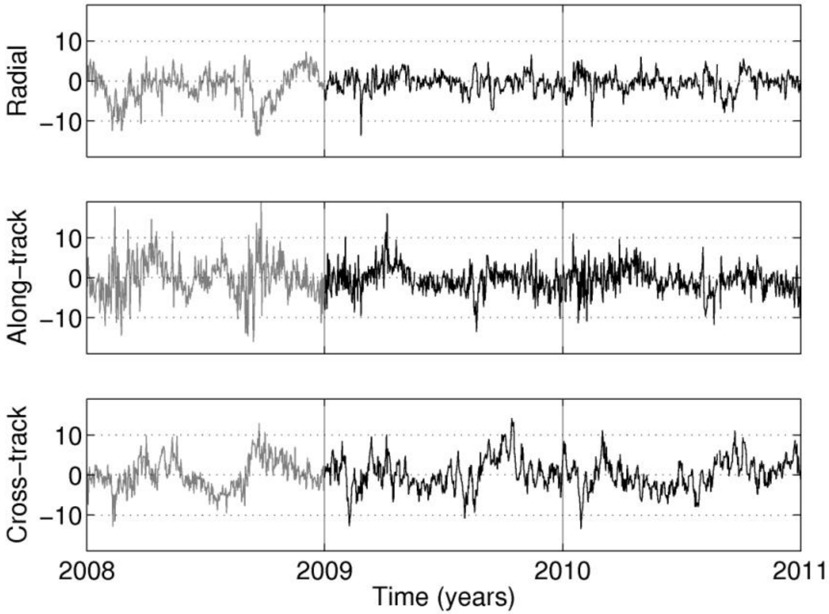
GPS



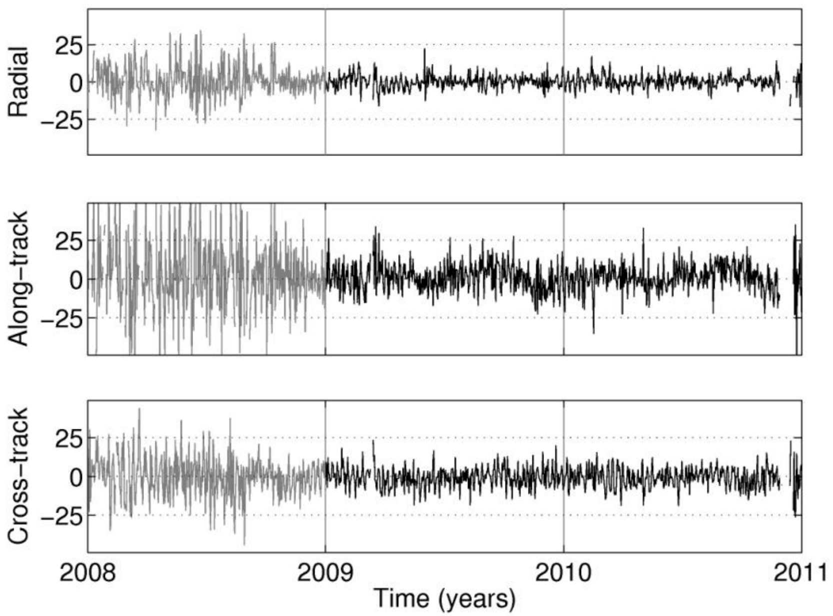
GLONASS

Results – Orbits

Orbit overlap differences (cm)



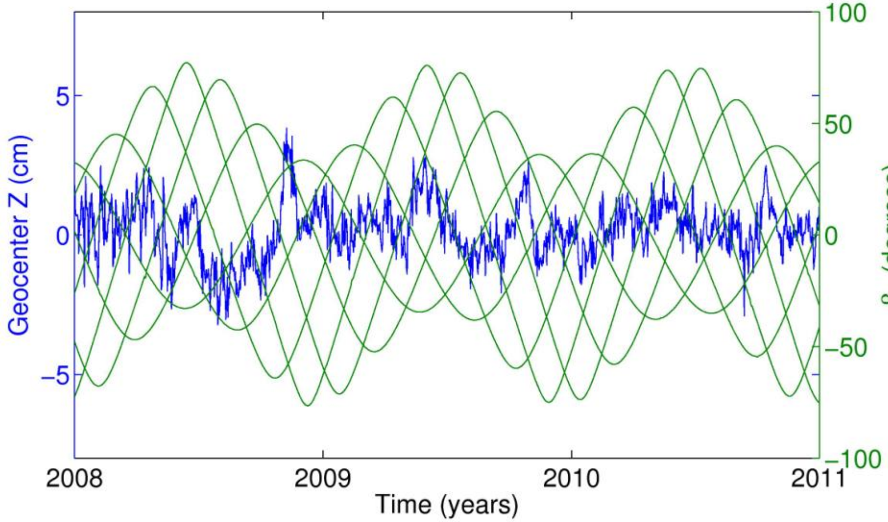
G03



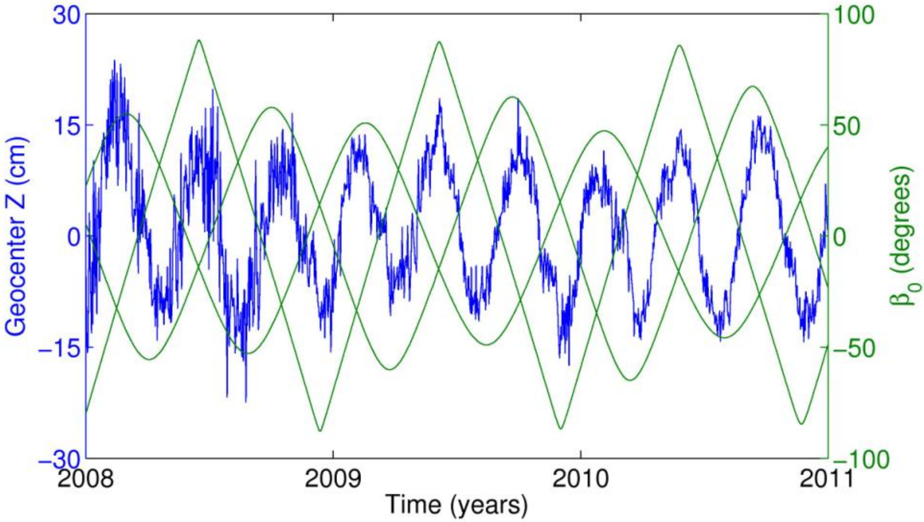
R17

Results – Geocenter Coordinates

Geocenter coordinates

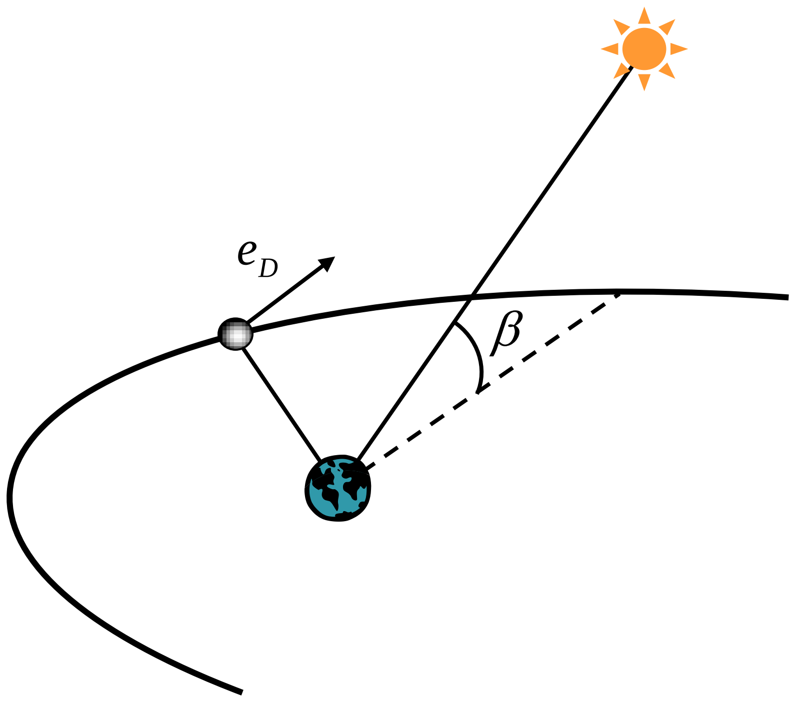


GPS Z-component



GLONASS Z-component

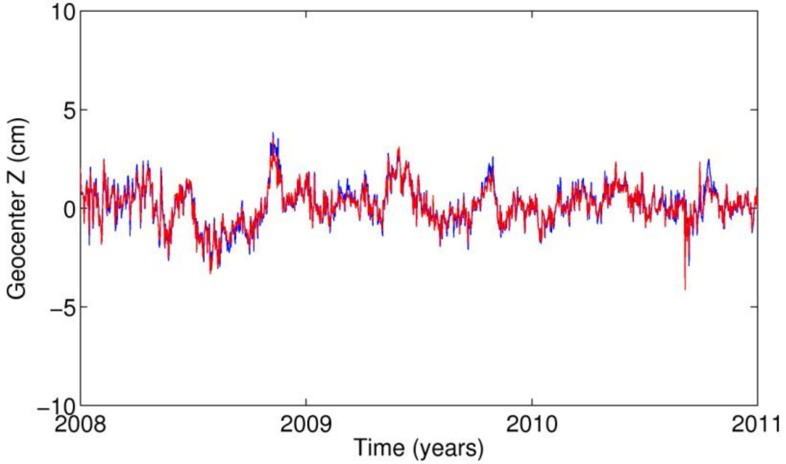
Results – Geocenter Coordinates



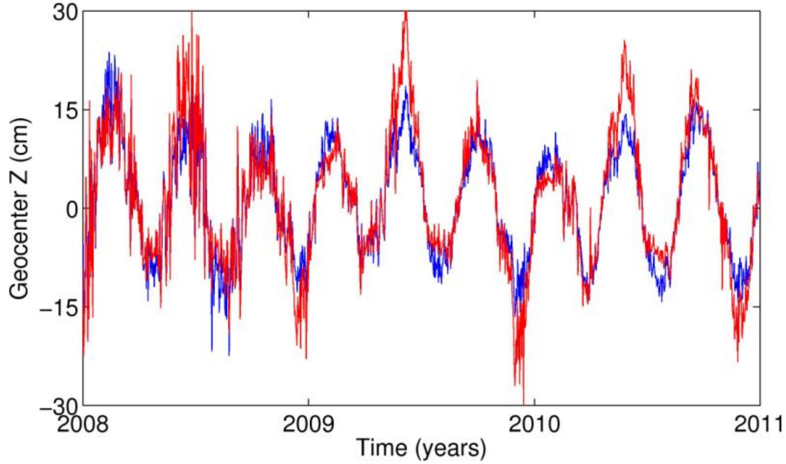
- Striking correlation of estimated *z*-coordinate with elevation angle β of the Sun above the orbital plane.
- Caused by strong correlation of estimated direct radiation pressure with *z*-coordinate, if the Sun stands perpendicular above the orbital plane.
- Effect can be explained by perturbation theory.

Results – Geocenter Coordinates

GCC Z-component: estimated, theory



GPS



GLONASS

The much larger effect for GLONASS is mainly caused by the fact that GLONASS only has three orbital planes, whereas GPS has six.

More information

Michael Meindl (2011)

Combined Analysis of Observations from Different Global Navigation Satellite Systems, Geodätisch-geophysikalische Arbeiten in der Schweiz, Vol 83.

Meindl M, Beutler G, Thaller D, Dach R, Jäggi A (2012)

***Geocenter coordinates estimated from GNSS data as viewed by perturbation theory,* Advances in Space Research, accepted for publication after minor review.**

Summary

It is now possible to generate independent and combined IGS-like solutions for GPS and GLONASS.

The combined GPS/GLONASS products are clearly better than the individual products.

The GNSS-specific solutions differ substantially in some products, in particular

- Estimates of z-component of geocenter
- Earth orientation parameters with high time resolution (e.g., hourly)

The differences are caused by correlation with orbit modeling.

Scientific applications

- depend on SLR for orbit validation
- would benefit very much from accelerometers on board the GNSS spacecrafts.