Geocenter and Polar Motion viewed by GPS and GLONASS

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11th Meeting of the National Space-Based Positioning, Navigation, and Timing (PNT) Advisory Board

The Melrose Hotel

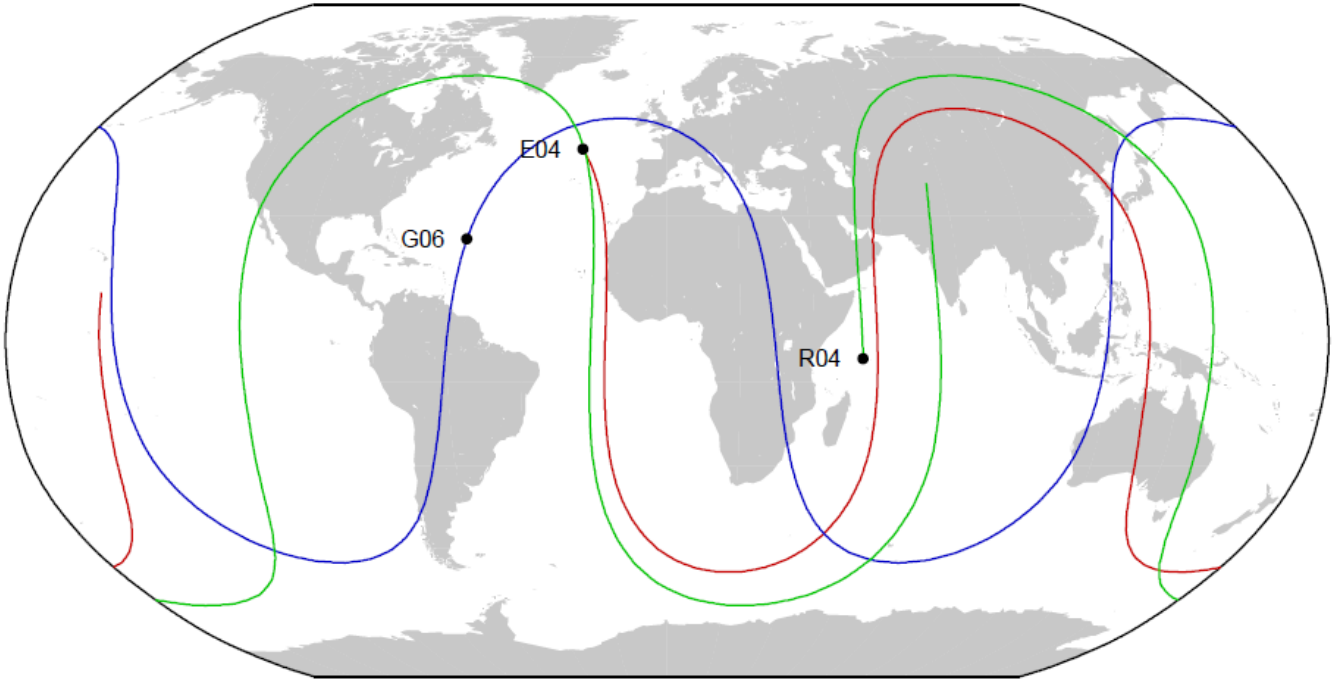
2430 Pennsylvania Ave NW

Washington DC

Topics

- **GPS, GLONASS, GALILEO: Status May 2013**
- **IGS = International *GNSS* Service**
- **The GPS and GLONASS-derived Geocenter**
- **The Earth‘s rotation axis in space and on its surface**
- **The GPS and GLONASS-derived polar motion**

GPS, GLONASS, GALILEO



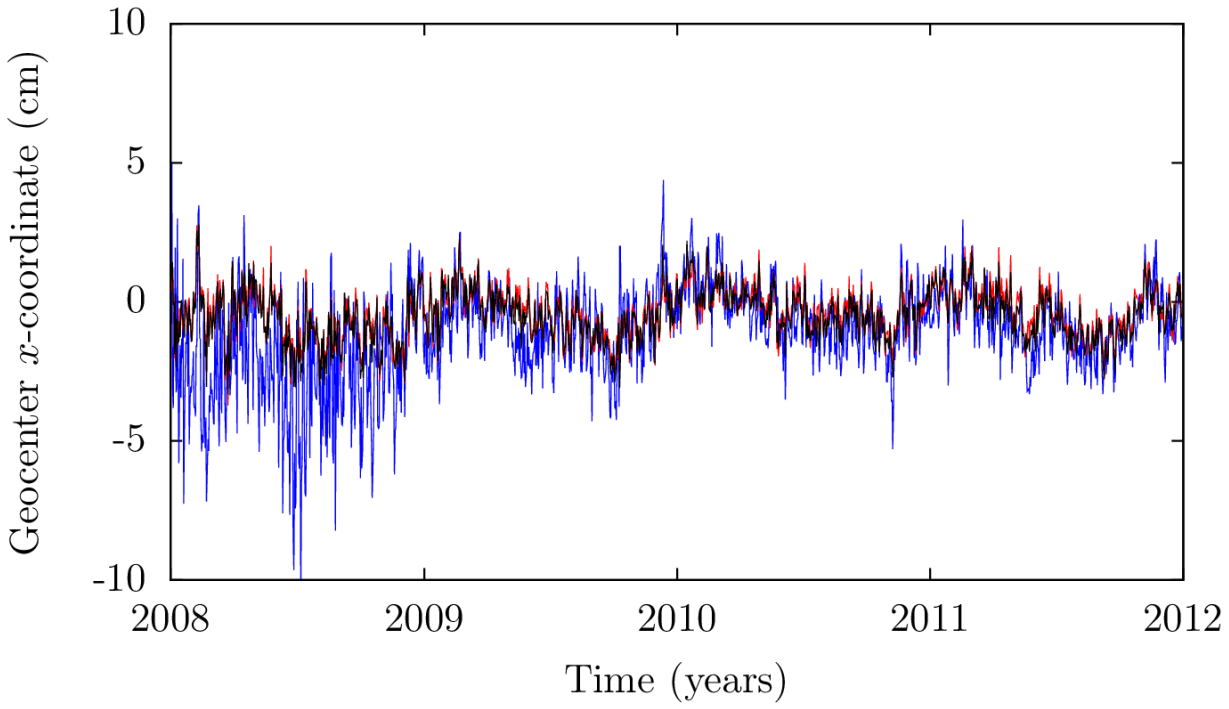
Daily Groundtracks of GPS, GLONASS and GALILEO.
GPS, GLONASS, Galileo have 1-day, 8-days, 10-days repeat cycles.

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 stand for providing continuity and leadership.

Center of Mass

Geocenter coordinates estimated with GPS, GLONASS**, and a** GPS/GLONASS **combination**



Center of Mass

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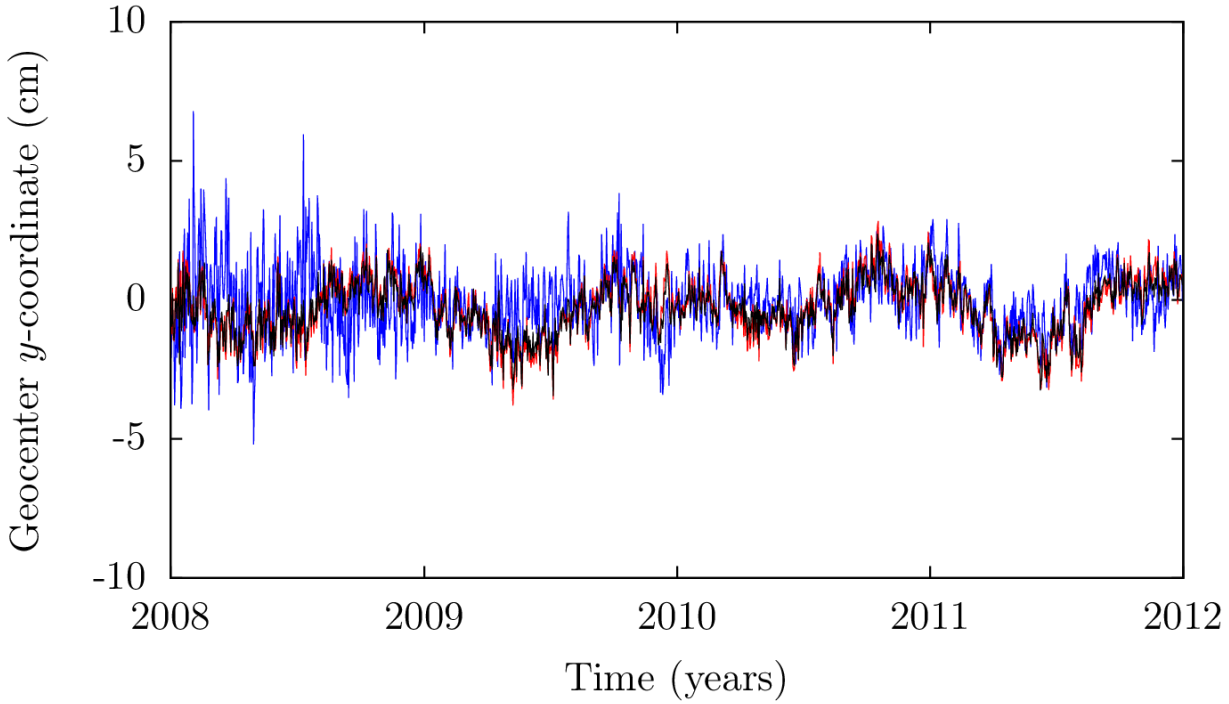

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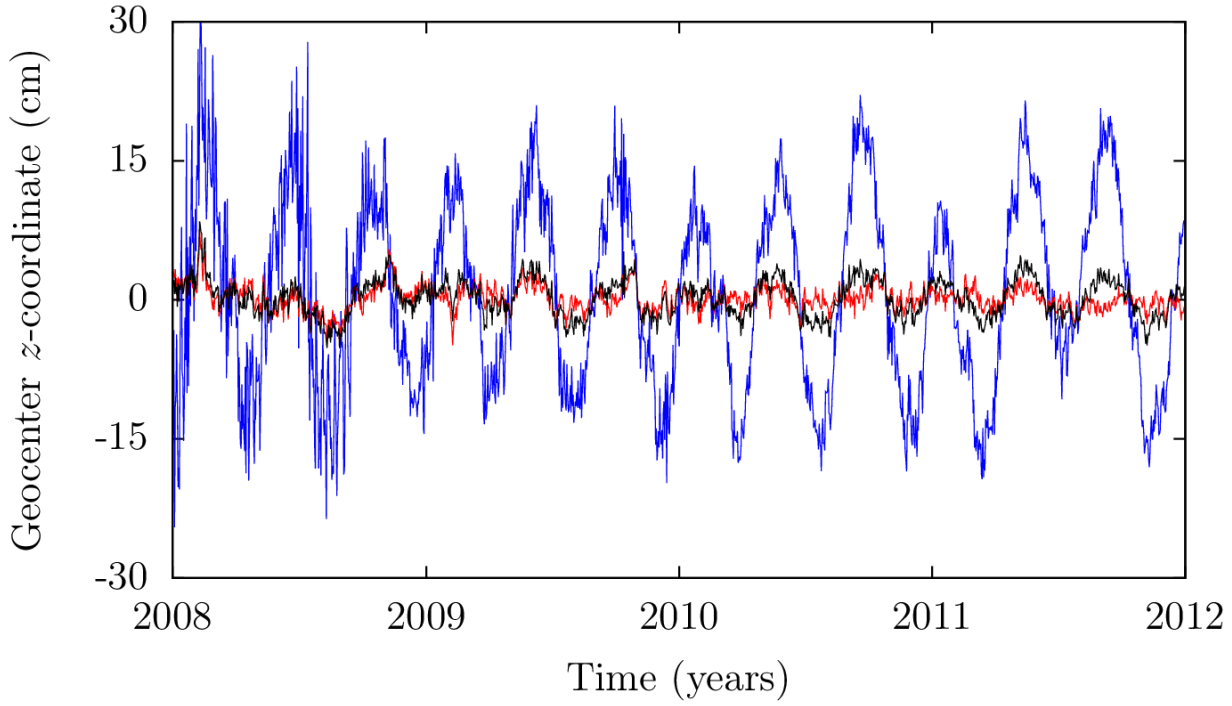
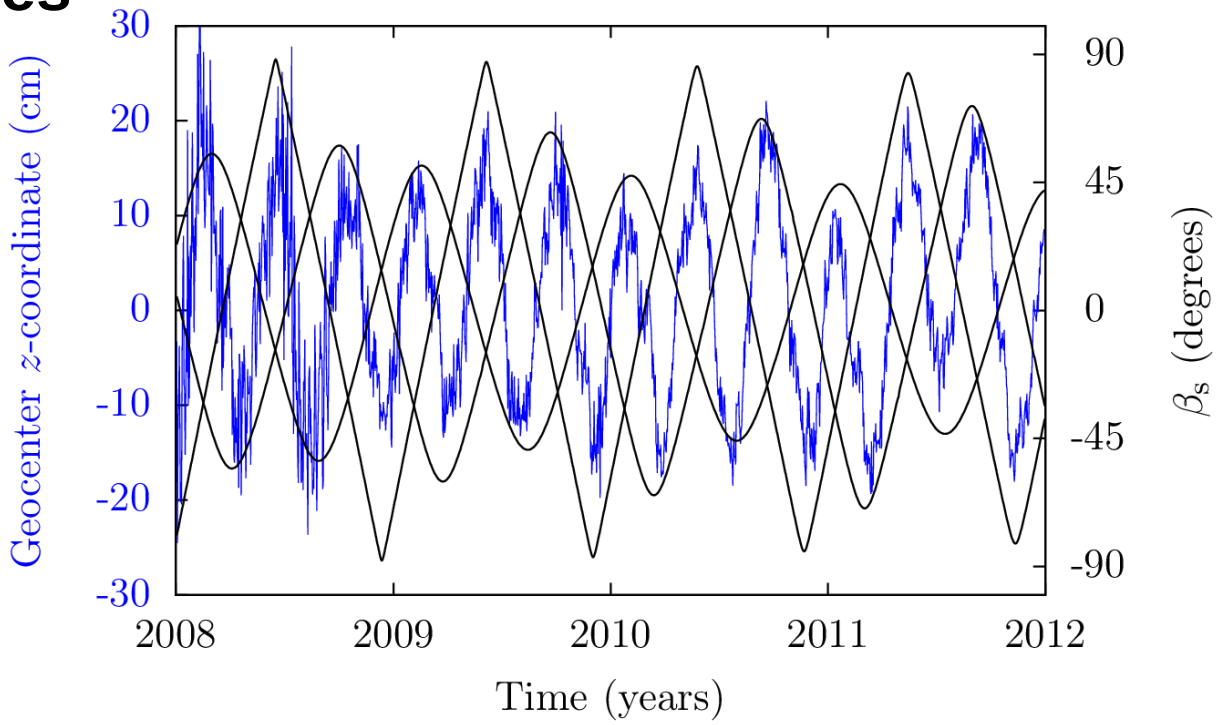


Center of Mass

Geocenter coordinates estimated with GLONASS and elevation β_s of the Sun above/below the orbital planes



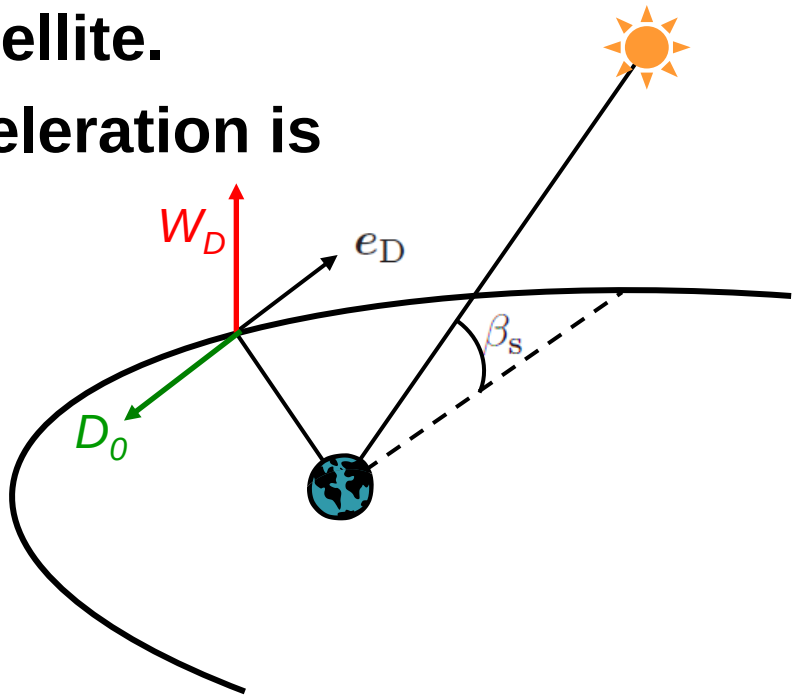
Center of Mass

Direct constant radiation pressure D_0 acts along the line Sun → Satellite and has to be determined in the analysis for each satellite.

Resulting out-of-plane acceleration is

$$W_D = D_0 \sin \beta_s$$

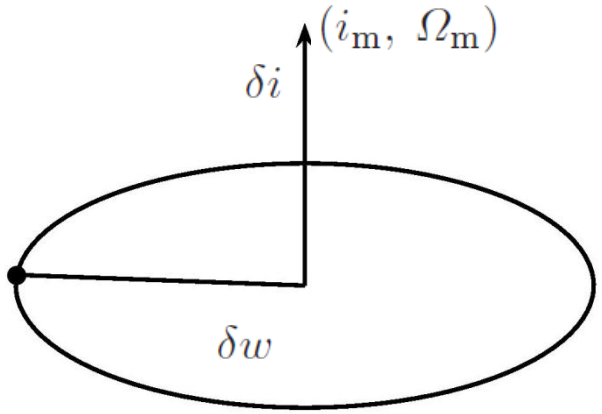
For $\beta = 90^o$, $D_0 = W_D$



CoM explained by Perturbation Theory

Only accelerations perpendicular to the orbital plane (W-direction) may alter an osculating plane

A non-vanishing constant W-component changes the orbital elements according to



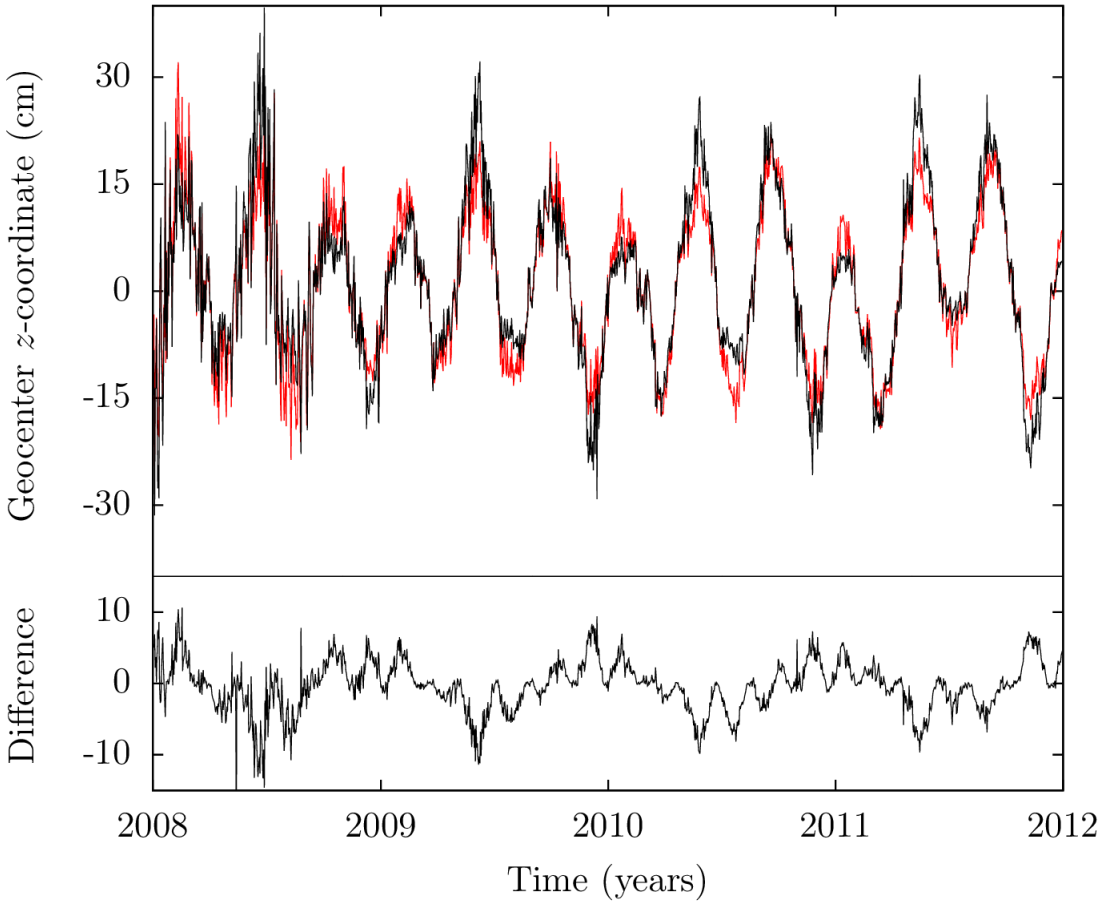
Satellite seemingly moves on a parallel plane shifted by $\delta w = \frac{W}{n^2}$

Pole of osculating orbit moves around a mean pole $(i_\mathrm{m},\ \Omega_\mathrm{m})$ on a circle with radius $\delta i = \frac{W}{n^2 a}$

CoM explained by Perturbation Theory

GLONASS

- estimated
- reconstructed



CoM explained by Perturbation Theory

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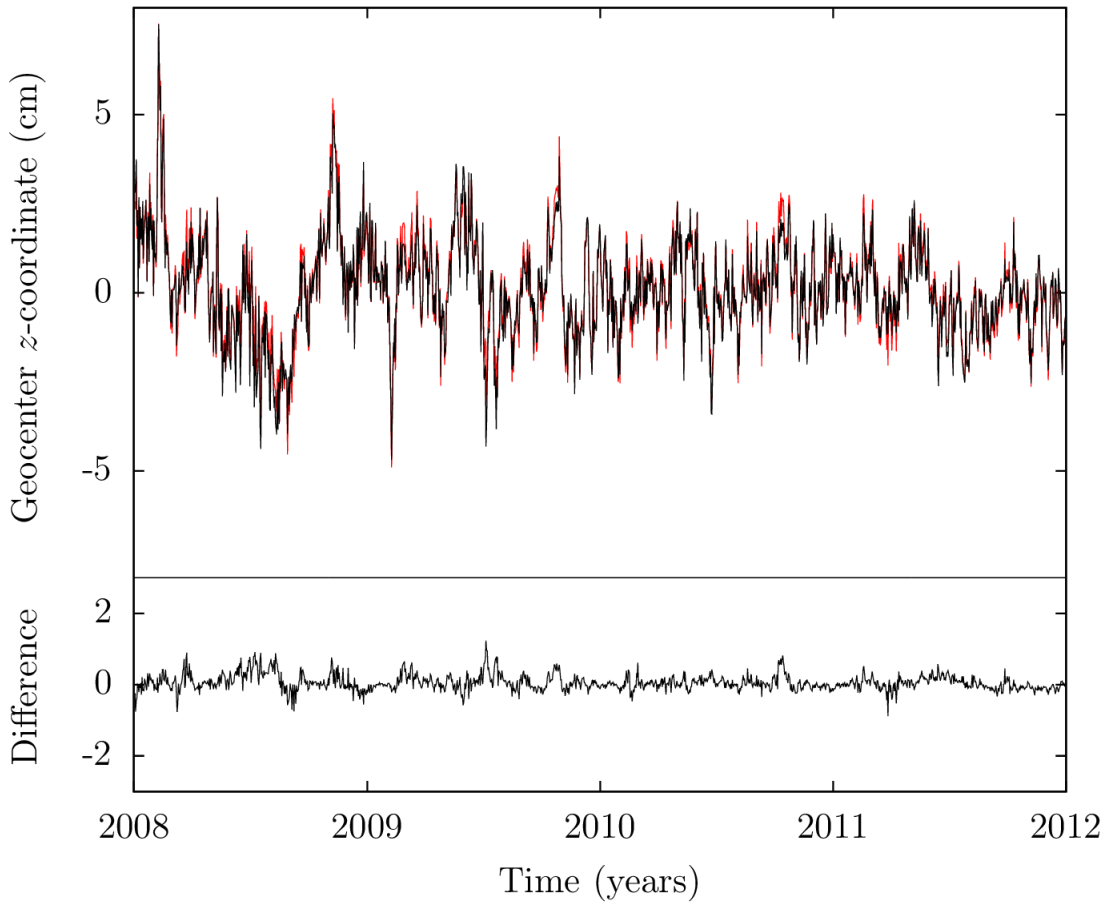


CoM explained by Perturbation Theory

Elevation of Sun w.r.t. the orbital planes

GPS $|\beta_s| \leq 78.5°$ **GLONASS** $|\beta_s| \leq 88.3°$

Number n_p of orbital planes

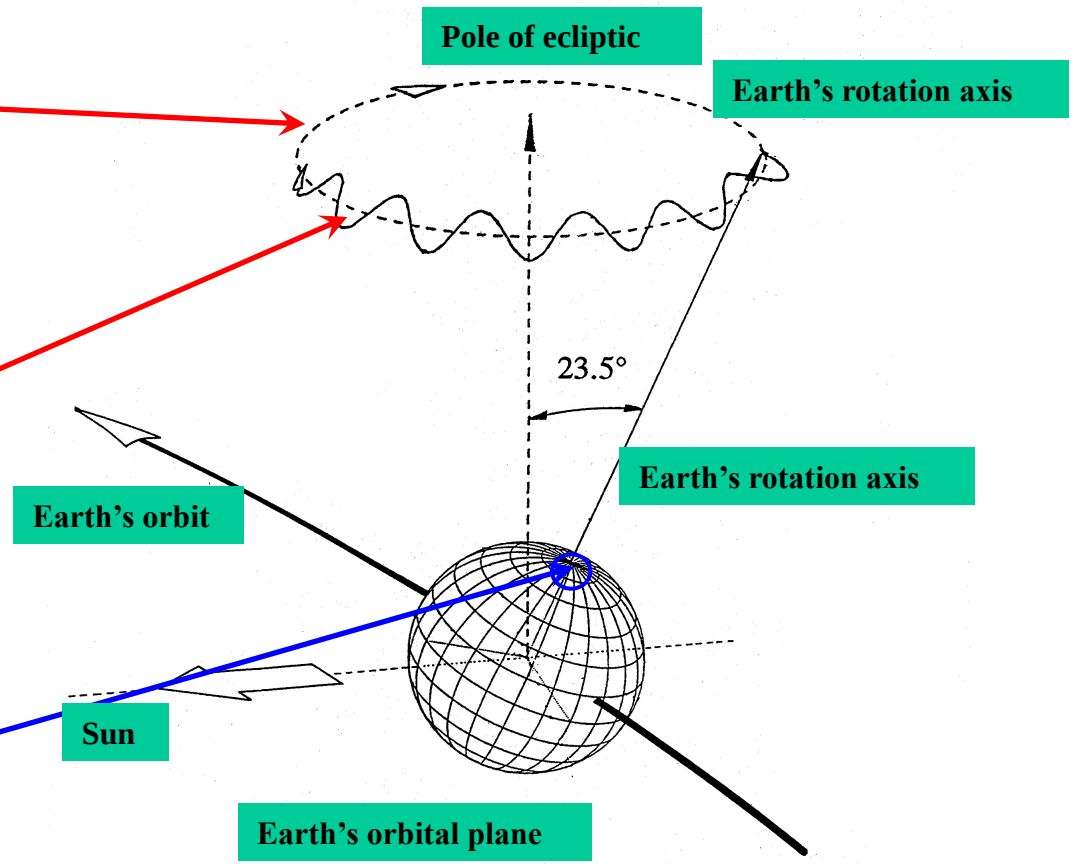
GPS $n_p = 6$ **GLONASS** $n_p = 3$

Polar Motion

Precession Amplitude: 23.5° Period: 26‘000 years

Nutation: Amplitude: ~ 9" Period: 18.6 years

Polar Motion: Rotation axis moves on Earth’s surface



Polar Motion & Earth's Center of Mass

Precession & Nutation and "UT1" (Universal Time defined by the Earth's Rotation) is monitored as a function of "UTC" (Universal Time defined by Atomic Clocks) using Very Long Baseline Interferometry (VLBI).

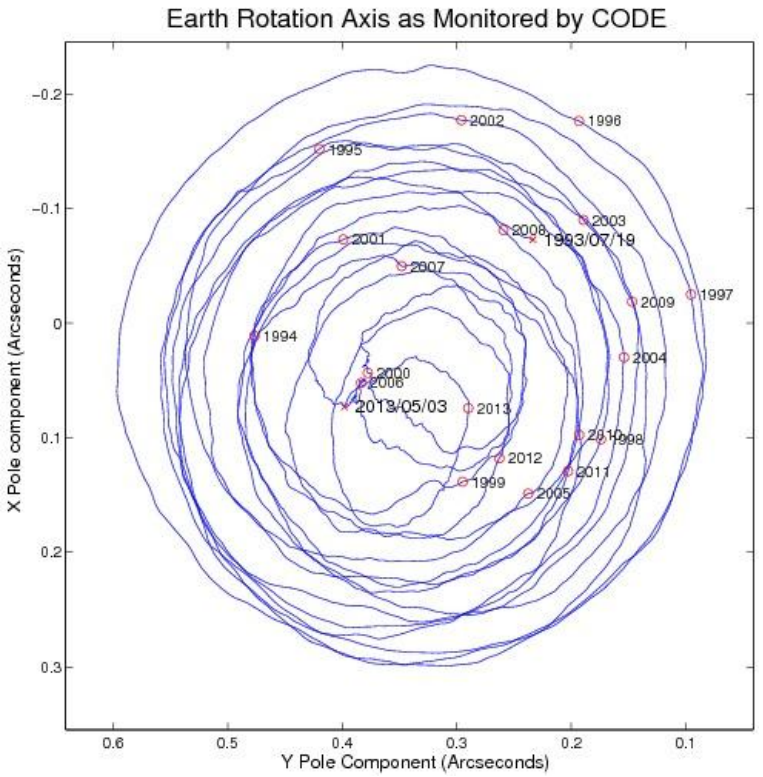
Polar motion (PM) and Length of Day (LoD) are monitored using GNSS, Satellite Laser Ranging (SLR), and VLBI.

The Earth's Center of Mass (CoM) is monitored primarily by SLR. GNSS may also be used.

The Earth's CoM may be established by Satellite Geodetic Methods because Earth satellites revolve about the Earth's CoM.

Basic assumption: CoM and PM are technique-independent – and in particular the same for all GNSS!

Polar Motion



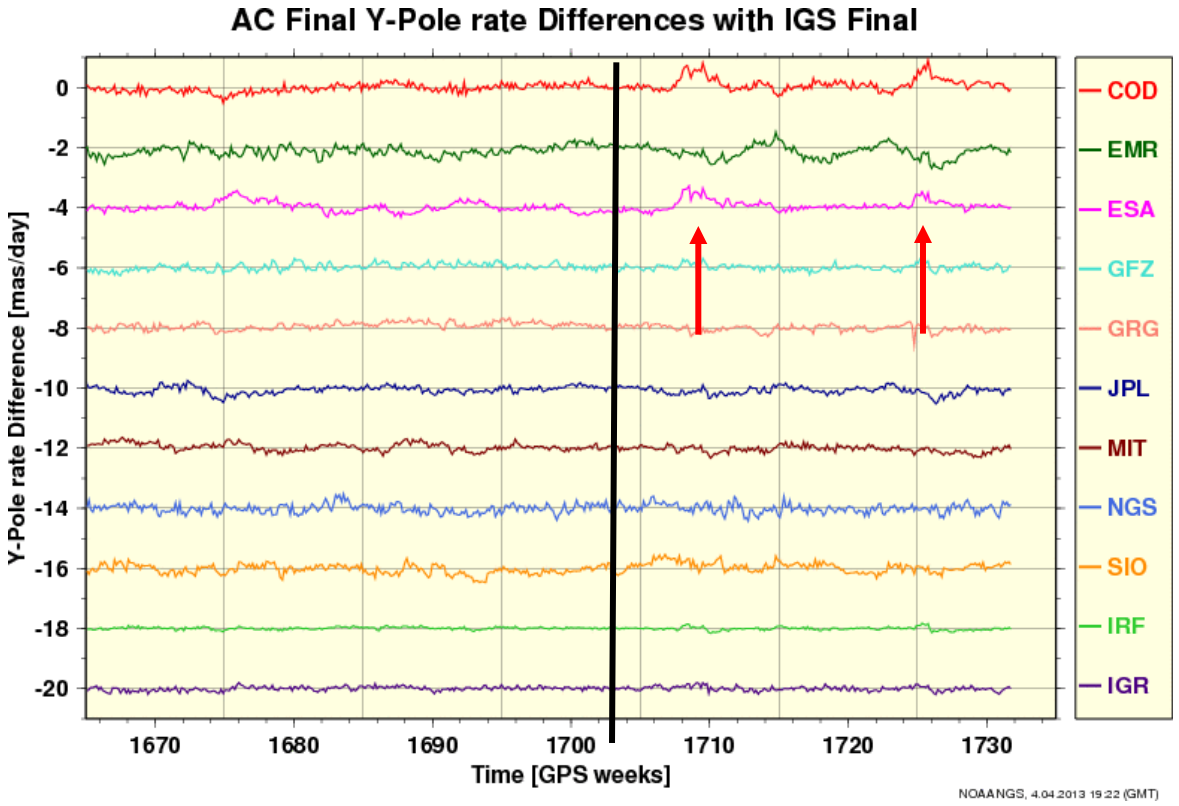
Polar motion monitored by the IGS between 1993 and 2013.

Diameter of figure about 7m, accuracy of daily estimates << 1cm!

Changing diameter of PM due to beat period (of 6 years) of Chandler and annual period

The Earth‘s pole moves „in bad circles of slowly varying radius“ around the Earth‘s figure axis (once in 430 days=Chandler period).

Similar Effects in Polar Motion

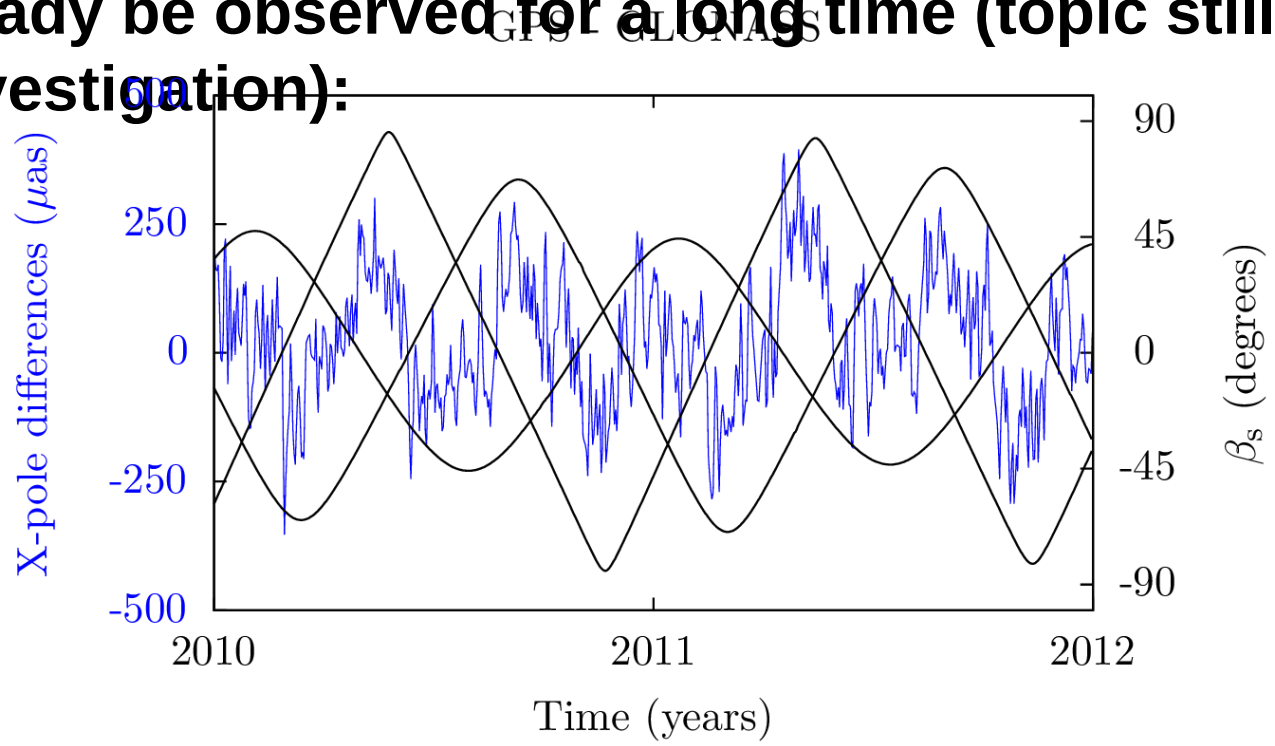


ERP-rates in y-coordinate of the pole (http://acc.igs.org/ ; IGS Analysis Center Coordinator Dr. Jake Griffiths)

→ Excursions for COD(COF) and ESA around weeks 1710 & 1725: Coincide with Sun's crossing (one of three) GLONASS orbital plane (Dr. Tim Springer (ESA))

Similar Effects in PM

The problem of GNSS-specific polar motion is could lready be observed for a long time (topic still under investigation):



Summary

Currently, we have the "interesting" situation that GPS and GLONASS "see" *slightly* different Polar Motion (PM) and Center(s) of Mass (CoM).

This result is nonsensical from the science perspective (it might make sense from the political perspective …).

The differences are caused (at least in part) by the constellations (3 vs. 6 orbital planes, inclinations of 64 vs. 55 degrees).

For more information consult:

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GNSS-derived Geocenter Coordinates Viewed by Perturbation Theory

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Illustrations taken from above presentation and from paper cited.