From GPS-only to multi-GNSS: getting ready …

G. Beutler
Astronomical Institute, University of Bern
Member of IAG Executive Committee
IGS Governing Board
Chair of GSAC (ESA)

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Topics

- GPS, GLONASS, GALILEO: Status June 2011
- IGS = International GNSS Service
- Ultra-Precise Clocks in Space
- SLR for the validation of GNSS- and LEO-orbits
GPS, GLONASS, GALILEO

GPS: USA, 31 satellites in 6 planes
GLONASS: 23 satellites in 3 planes

GALILEO: GIOVE-A, -B + 4 IOV-satellites to be launched from 2011 onwards

All GLONASS and GALILEO satellites are equipped with SLR reflectors

Only one GPS Satellite left in orbit with SLR reflectors
Groundtracks of GPS, GLONASS and GALILEO over one day
GPS visibility for a particular site

The 31 GPS satellite tracks repeat after one sidereal day (23h56m).

Azimuth-Elevation Plot of the GPS constellation as seen from Zimmerwald(CH)
GLONASS visibility for a particular site

The 23 GLONASS satellite tracks repeat after 8 sidereal days (17 revolutions).
Smaller polar gap (compared to GPS, Galileo)
Azimuth–Elevation Plot of the GLONASS constellation as seen from Zimmerwald(CH)
Tracks over 10 days
Galileo visibility for a particular site

The 27 Galileo satellite tracks repeat after 10 sidereal days of 23h56m (17 revolutions)

Azimuth – Elevation Plot of the Galileo constellation as seen from Zimmerwald (CH)

Polar gap approximately the same as that of GPS

Tracks over 10 days
PDOP (Positional Dilution of Precision) for GPS, GLONASS, Galileo & combined over ten days.
PDOP of GNSS

Station: Zimmerwald, Switzerland

Spectral analysis of PDOP (Positional Dilution of Precision) for GPS, GLONASS, Galileo & combined → spectral lines are greatly reduced in the combination.
IGS: Combined GPS/GLONASS Analysis

In 1995 there were about 100 GPS receivers in the IGS net, today there are more than 300.
In 1998 there were a few GLONASS receiver in the IGS net, today there are about 140.
Consistency of IGS-derived GPS (left) and GLONASS (right) orbits: today both on the 1-2 cm level (weekly report of IGS ACC)
IGS: Reprocessing

Coordinate time series for the IGS sites based on original IGS solutions show systematic effects.
IGS: Reprocessing

Entire IGS dataset was re-analyzed using the latest software developments and models → no biases left in the solutions!
High-Accuracy Clocks in Space

In 1984 G. Beutler et al. wrote:

„In the authors‘ opinion, the best way of modelling the clocks is the following: define a statistical model of clock performances using available information on clock offset, drift, jitter. This leads to a simple stochastic differential equation ... for the clock synchronization error as a function of time ...“

High-Accuracy Clocks in Space

Potential impact:
Clock prediction for real-time applications: Orbit errors might become the limiting factor for prediction.

Explicit/Implicit Double-difference approach may have to be left.

But: The algorithms have to be kept manageable for the user! → Challenge

From Hugentobler et al. (2010) „Evaluation of GIOVE Satellite Clocks using the CONGO Network“. Allan deviations derived from an orbit & clock analysis using the data of the CONGO network of GNSS receivers (deployed by DLR and BKG, Germany).
The Case for SLR Reflectors on GNSS and LEO Satellites

Modeling the Phase Center Variations on the GOCE satellite. Mean Residuals of SLR Observations in 2 x 2 deg bins in the satellite-fixed reference frame before (left) and after (right) PCV modelling. Scale in mm.
The Case for SLR Reflectors on GNSS and LEO Satellites

SLR Residuals based on Orbit without (top) and with (bottom) PCVs.

→ SLR provided an external validation of the determined PCV model

The Case for SLR Reflectors on GNSS and LEO Satellites

- SLR reflectors on board GNSS and other satellites allow it to validate their orbits, which were determined using the GNSS observables (Code and Carrier Phase).
- SLR provides an absolute measurement between observers on the Earth’s surface and the satellites (no ambiguities, no wet tropospheric refraction)
- All current and future GLONASS satellites have/will have Laser reflectors → orbit models can be easily validated
- GIOVE-A and –B have SLR SLR reflectors
- All Galileo IOV satellites will have SLR reflectors
- All future GPS satellites should be equipped with SLR reflectors!
Acknowledgements

International GNSS Service
on the step to the multi-GNSS age

R. Dach
Astronomisches Institut, Universität Bern
Sidlerstrasse 5, CH-3012 Bern

U. Hugentobler
Institut für Astronomische und Physikalische Geodäsie,
Technische Universität München

Satellite methods for positioning in modern geodesy and navigation
Satelitarne metody wyznaczania pozycji we współczesnej geodezji i nawigacji
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International Association of Geodesy