Global Multi–GNSS Processing at CODE

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Outline

Global Multi–GNSS Processing at CODE:

1. Development of GLONASS within the last five years
2. Orbit characteristics for the individual GNSS
3. Impact of adding GLONASS to GPS measurements
   ■ for navigation purposes
   ■ on global parameters
4. Summary and Outlook
GPS/GLONASS Orbit Comparison

Number of active GPS and GLONASS satellites

MJD

Number of satellites

2003 2004 2005 2006 2007 2008


GNSS GPS GLONASS

MJD

53000 53200 53400 53600 53800 54000 54200 54400 54600
Distribution of the combined GPS/GLONASS receivers in the IGS–network
status: July 2003 (day of year 2003:182)

Receivers tracking:
★ GPS/GLONASS (21)
● only GPS (137)
Development of the IGS multi–GNSS network

Distribution of the combined GPS/GLONASS receivers in the IGS–network
status: May 2008 (day of year 2008:140)

Receivers tracking: ★ GPS/GLONASS (53) ● only GPS (120)
Number of the combined GPS/GLONASS receivers in the IGS–network

<table>
<thead>
<tr>
<th>Year</th>
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Number of multi–GNSS stations:

- Rapid solution
- Final solution
Development of GLONASS satellite orbit accuracy provided by CODE

GPS satellites

GLONASS satellites

Median of RMS in cm

MJD

GPS/GLONASS Orbit Comparison

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GPS/GLONASS Orbit Characteristics

Ground track for the GPS constellation

Ground track for G06 for one day

day of year 2008:060
Ground track for the GPS constellation

Ground track for G06 for ten days

day of year 2008:060 to 069
GPS/GLONASS Orbit Characteristics

Ground track for the GPS constellation
Ground track for all satellites for ten days

day of year 2008:060 to 069
Ground track for the GLONASS constellation

Ground track for R04 for one day

day of year 2008:060
Ground track for the GLONASS constellation

Ground track for R04 for ten days

day of year 2008:060 to 069
GPS/GLONASS Orbit Characteristics

Ground track for the GLONASS constellation

Ground track for R01 to R08 for ten days

day of year 2008:060 to 069
GPS/GLONASS Orbit Characteristics

Ground track for the GLONASS constellation

Ground track for all satellites for ten days

day of year 2008:060 to 069
GPS/GLONASS Orbit Characteristics

Elevation–Azimuth–Diagram
Zimmerwald (Lat: 46° 52'; Lon: 7° 28’)

day of year 2008:060 to 069
GPS/GLONASS Orbit Characteristics

Elevation–Azimuth–Diagram
Zimmerwald (Lat: 46° 52’; Lon: 7° 28’)

Day of year 2008: 060 to 069

Satellite G06
Satellite R04
GPS/GLONASS Orbit Characteristics

Elevation–Azimuth–Diagram

Ulaanbataar (Lat: 47° 40'; Lon: 107° 3’)

day of year 2008:060 to 069
GPS/GLONASS Orbit Characteristics

Number of stations tracking a GPS satellite

Assuming the CODE final network with $5^\circ$ cut–off and 15 minutes sampling, day of year 2008:060
GPS/GLONASS Orbit Characteristics

Number of stations tracking a GLONASS satellite

Assuming the CODE final network with 5° cut–off and 15 minutes sampling, day of year 2008:060
GPS/GLONASS Orbit Characteristics

Total number of observations per day and satellite

Assuming the CODE final network with 5° cut–off and 15 minutes sampling, day of year 2008:060
GPS/GLONASS Orbit Characteristics

Total number of observations per day and satellite
Mean value after eight days

Assuming the CODE final network with $5^\circ$ cut-off and 15 minutes sampling, day of year 2008:060 to 067
PDOP: Constellation Effects

Number of Satellites in View
Example: station Zimmerwald

Days of year 2008

Number of satellites

GNSS  GPS  GLONASS

elevation cut-off $5^\circ$, day of year 2008:060 to 069
PDOP: Constellation Effects

PDOP values for satellite constellation in view
Example: station Zimmerwald

elevation cut–off 5°, day of year 2008:060 to 069
Spectra of PDOP values for satellite constellations

Example: station Zimmerwald

Days

elevation cut–off 5°, day of year 2008:020 to 069
PDOP: Constellation Effects

Spectra of PDOP values for satellite constellations
Example: station Zimmerwald

elevation cut–off 5°, day of year 2008:020 to 069
Spectra of PDOP values for satellite constellations

Example: station Zimmerwald

elevation cut–off 5°, day of year 2008:020 to 069
Performance of a Kinematic Positioning

CODE EPN network

Receivers tracking:

- GPS/GLONASS (24)
- only GPS (29)

CODE EPN solution for day of year 2007:034 to 089
Performance of a Kinematic Positioning

Results from a kinematic positioning
Example: station Zimmerwald (ZIM2)

Day of year 2008

CODE EPN solution for day of year 2007:034 to 089
The Allan deviation reflects the noise behavior of a time series.

It is comparable with the RMS of epoch differences.

The time interval gives the length between these epochs.
Performance of a Kinematic Positioning

Allan deviation from a kinematic positioning
Example: station Zimmerwald (ZIM2)

North component

East component

CODE EPN solution for day of year 2007:034 to 089
Comparisons of Global Solutions

Repeatability of daily station coordinate solutions

RMS of 8 daily coordinate solutions

Solution includes
- only GPS measurements

CODE final solution for day of year 2007:060 to 067
Comparisons of Global Solutions

Repeatability of daily station coordinate solutions

RMS of 8 daily coordinate solutions

Solution includes
- only GPS
- GPS & GLONASS measurements

CODE final solution for day of year 2007:060 to 067
Comparisons of Global Solutions

Repeatability of daily station coordinate solutions
RMS of 8 daily coordinate solutions

Solution includes
- only GPS
- GPS & GLONASS measurements

CODE final solution for day of year 2007:060 to 067
Summary and Conclusions

What did we learn from studying the orbit geometry?
What did we learn from studying the orbit geometry?

The GPS constellation
- has a strong repetition rate of a sideral day.

The GLONASS constellation
- has a higher variability (repetition rate of 8 sideral days after 17 revolutions).
What did we learn from studying the orbit geometry?

The GPS constellation
- has a strong repetition rate of a sideral day.
- is longitude dependent because each satellite follows its own ground track.

The GLONASS constellation
- has a higher variability (repetition rate of 8 sideral days after 17 revolutions).
- is independent from the longitude because of the shift in the ground track for each day.
Summary and Conclusions

What did we learn from studying the orbit geometry?

The GPS constellation
- has a strong repetition rate of a sideral day.
- is longitude dependent because each satellite follows its own ground track.
- has the dominant frequency at a sideral day in the spectrum of the variation of the satellite geometry.

The GLONASS constellation
- has a higher variability (repetition rate of 8 sideral days after 17 revolutions).
- is independent from the longitude because of the shift in the ground track for each day.
- has the dominant frequency at once per revolution in the spectrum of the variation of the satellite geometry (uncertainty of the orbits?).
Summary and Conclusions

Why to generate a multi–GNSS solution?

- to reduce the impact of the strong GPS constellation frequency of one sidereal day to the obtained products.
- to improve products with a high resolution in time ($\sqrt{n}$–law, robustness).
- to reduce the impact of multipath to the solution.
- to be in place for including the new GNSS (Galileo, Compass?) as soon as data are available.
Summary and Conclusions

Why to generate a multi–GNSS solution?

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What can a multi–GNSS solution never provide?

- to replace general improvements of the GNSS modelling (e.g., troposphere modelling).
IGS and multi–GNSS

IGS: from GPS to GNSS service

- since January 2008: two AC provide full multi–GNSS solutions
- merged GPS/GLONASS orbit file from the two final combinations
- development of a full multi–GNSS (orbit) combination procedure
- densification of the GLONASS tracking network in North America