GLONASS Satellite Orbit Modelling

R. Dach¹, A. Sušnik¹, A. Grahsl¹, A. Villiger¹,
D. Arnold¹, L. Prange¹, S. Schaer¹,², A. Jäggi¹

1 Astronomical Institute, University of Bern, Switzerland
2 Swiss Federal Office of Topographie, swisstopo

IGS Workshop
Session #08: Orbit Modelling
03–07. July 2017, Paris, France
Overview

Motivation

Investigating indicators for orbit characteristics

Estimating satellite antenna offsets

Applying the estimated satellite antenna offsets

Discussion and summary
Motivation

PS07-10: U. Meyer, Y. Jean, D. Arnold, A. Jäggi

EGSIEM: scientific combination service for monthly gravity fields
Motivation

GNSS Reprocessing in 2015:

Product availability:

<table>
<thead>
<tr>
<th>GNSS satellite orbits:</th>
<th>GPS</th>
<th>GLONASS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>since 1994</td>
<td>since 2002</td>
</tr>
<tr>
<td>GNSS satellite clock corrections:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>sampling 30 s:</td>
<td>since 2000</td>
<td>since 2008</td>
</tr>
<tr>
<td>sampling 5 s:</td>
<td>since 2003</td>
<td>since 2010</td>
</tr>
</tbody>
</table>

PS08-04: A. Sušnik, D. Arnold, A. Villiger, R. Dach, A. Jäggi
Validating EGSIEM Reprocessing Products by LEO POD and PPP
Motivation

SLR residuals for satellite SVN 736 (R09/R16)

Residuals in mm

Orbits are based on a three-day long-arc solutions.
Motivation

**SLR residuals for satellite SVN 737 (R12)**

Orbits are based on a three-day long-arc solutions.
Investigating indicators for orbit characteristics

Orbit misclosures for satellite SVN 736 (R09/R16) in mm

Orbits are based on a three-day long-arc solutions.
Investigating indicators for orbit characteristics

Orbit misclosures for satellite SVN 737 (R12) in mm

Orbits are based on a three-day long-arc solutions.

Astronomical Institute, University of Bern
Investigating indicators for orbit characteristics

Orbit misclosures for satellite SVN 736 (R09/R16) in mm

Orbits are based on clean one-day solutions.
Investigating indicators for orbit characteristics

Orbit misclosures for satellite SVN 737 (R12) in mm

Orbits are based on clean one-day solutions.
Investigating indicators for orbit characteristics

Estimated SRP parameters for satellite SVN 736 (R09/R16) in nm/s²

Orbits are based on clean one-day solutions.
Investigating indicators for orbit characteristics

B1C

B1S

D2C

D2S


Astronomical Institute, University of Bern
Investigating indicators for orbit characteristics

Estimated SRP parameters for satellite SVN 737 (R12) in nm/s²

Orbits are based on clean one-day solutions.
Investigating indicators for orbit characteristics

Estimated SRP parameters for satellite SVN 736 (R09/R16) in nm/s²

Orbits are based on a three-day long-arc solutions.
Investigating indicators for orbit characteristics

Astronomical Institute, University of Bern
Investigating indicators for orbit characteristics

Estimated SRP parameters for satellite SVN 737 (R12) in $\text{nm/s}^2$

Orbits are based on a three-day long-arc solutions.
Investigating indicators for orbit characteristics

D2S


D2C


D1S


D1C

Investigating indicators for orbit characteristics

What do we know so far?
Investigating indicators for orbit characteristics

What do we know so far?

- Some of the GLONASS satellites show unexpected big SLR residuals after a few years of lifetime.

Some satellites had to be excluded from the SLR-validation in the paper Arnold et al., 2015 because of unexpected behaviour.
What do we know so far?

- Some of the GLONASS satellites show unexpected big SLR residuals after a few years of lifetime. Some satellites had to be excluded from the SLR-validation in the paper Arnold et al., 2015 because of unexpected behaviour.

- Orbit misclosures do only marginally react on this phenomena for three-day arc. A bigger effect is visible for one-day arcs.
What do we know so far?

- Some of the GLONASS satellites show unexpected big SLR residuals after a few years of lifetime. Some satellites had to be excluded from the SLR-validation in the paper Arnold et al., 2015 because of unexpected behaviour.

- Orbit misclosures do only marginally react on this phenomena for three-day arc. A bigger effect is visible for one-day arcs.

- The SRP parameters show a clear deviation from the usual pattern in these periods.
Investigating indicators for orbit characteristics

What do we know so far?

- Some of the GLONASS satellites show unexpected big SLR residuals after a few years of lifetime. Some satellites had to be excluded from the SLR-validation in the paper Arnold et al., 2015 because of unexpected behaviour.

- Orbit misclosures do only marginally react on this phenomena for three-day arc. A bigger effect is visible for one-day arcs.

- The SRP parameters show a clear deviation from the usual pattern in these periods.

- The shown effects are more pronounced in the ECOM2 than with the classical ECOM (periodic terms in $D$-direction added).
Estimated satellite antenna offsets (SAO) for satellite SVN 737 (R12) in m

Orbits are based on a three-day long-arc solutions.
Estimated satellite antenna offsets (SAO) for satellite SVN 736 (R09/R16) in m

Orbits are based on a three-day long-arc solutions.
Estimating satellite antenna offsets (SAO) for satellite SVN 735 (R24) in m

Orbits are based on a three-day long-arc solutions.
Estimated satellite antenna offsets (SAO) for satellite SVN 734 (R05) in m

Orbits are based on a three-day long-arc solutions.
Detecting discontinuities

How reliably detect the discontinuities?
Detecting discontinuities

How reliably detect the discontinuities?

- annual SAO solutions
Detecting discontinuities

How reliably detect the discontinuities?

- annual SAO solutions shifted by one week
Detecting discontinuities

How reliably detect the discontinuities?

- annual SAO solutions shifted by one week
Detecting discontinuities

How reliably detect the discontinuities?

- annual SAO solutions shifted by one week
Detecting discontinuities

How reliably detect the discontinuities?

- annual SAO solutions shifted by one week
Detecting discontinuities

How reliably detect the discontinuities?

- annual SAO solutions shifted by one week
Detecting discontinuities

How reliably detect the discontinuities?

- annual SAO solutions shifted by one week
Detecting discontinuities

How reliably detect the discontinuities?

- annual SAO solutions shifted by one week
Detecting discontinuities

How reliably detect the discontinuities?

- annual SAO solutions shifted by one week
Detecting discontinuities

How reliably detect the discontinuities?

• annual SAO solutions shifted by one week
Detecting discontinuities

How reliably detect the discontinuities?

- annual SAO solutions shifted by one week
Detecting discontinuities

How reliably detect the discontinuities?

- annual SAO solutions shifted by one week
Detecting discontinuities

How reliably detect the discontinuities?

- annual SAO solutions shifted by one week
- compute differences between solution $n$ and $n + 50$
Detecting discontinuities

How reliably detect the discontinuities?

- annual SAO solutions shifted by one week
- compute differences between solution $n$ and $n + 50$
Detecting discontinuities

How reliably detect the discontinuities?

- annual SAO solutions shifted by one week
- compute differences between solution $n$ and $n + 50$
Detecting discontinuities

How reliably detect the discontinuities?

- annual SAO solutions shifted by one week
- compute differences between solution $n$ and $n + 50$
Detecting discontinuities

How reliably detect the discontinuities?

- annual SAO solutions shifted by one week
- compute differences between solution $n$ and $n + 50$
Detecting discontinuities

How reliably detect the discontinuities?

- annual SAO solutions shifted by one week
- compute differences between solution $n$ and $n + 50$
Detecting discontinuities

How reliably detect the discontinuities?

- annual SAO solutions shifted by one week
- compute differences between solution $n$ and $n + 50$
Detecting discontinuities

How reliably detect the discontinuities?

- annual SAO solutions shifted by one week
- compute differences between solution $n$ and $n + 50$
Detecting discontinuities

How reliably detect the discontinuities?

- annual SAO solutions shifted by one week
- compute differences between solution $n$ and $n + 50$
Detecting discontinuities

How reliably detect the discontinuities?

- annual SAO solutions shifted by one week
- compute differences between solution $n$ and $n + 50$
Detecting discontinuities

How reliably detect the discontinuities?

- annual SAO solutions shifted by one week
- compute differences between solution $n$ and $n + 50$
Detecting discontinuities

How reliably detect the discontinuities?

- annual SAO solutions shifted by one week
- compute differences between solution \( n \) and \( n + 50 \)
Detecting discontinuities

How reliably detect the discontinuities?

- annual SAO solutions shifted by one week
- compute differences between solution $n$ and $n + 50$
- search local extrema in the differences
Detecting discontinuities

How reliably detect the discontinuities?

- annual SAO solutions shifted by one week
- compute differences between solution $n$ and $n + 50$
- search local extrema in the differences
- discontinuity is assumed if extrema has a magnitude of at least be 3 cm
Estimated satellite antenna offsets (SAO) for satellite SVN 734 (R05) in m

Orbits are based on a three-day long-arc solutions.
Estimated satellite antenna offsets (SAO) for satellite SVN 735 (R24) in m

Orbits are based on a three-day long-arc solutions.
Applying the estimated satellite antenna offsets

Estimated SRP parameters for satellite SVN 736 (R09/R16) in nm/s²

Orbits are based on a three-day long-arc solutions.

Astronomical Institute, University of Bern
Applying the estimated satellite antenna antenna offsets

- B1C
- B1S
- D2C
- D2S

Using estimated and original SAOs

Astronomical Institute, University of Bern
Applying the estimated satellite antenna offsets

Estimated SRP parameters for satellite SVN 737 (R12) in $\text{nm/s}^2$

Orbits are based on a three-day long-arc solutions.
Applying the estimated satellite antenna offsets

- Using estimated original SAOs

- B1C
- B1S
- D2C
- D2S

Applying the estimated satellite antenna offsets

SLR residuals for satellite SVN 736 (R09/R16)

Residuals in mm

Orbits are based on a three-day long-arc solutions.
Applying the estimated satellite antenna offsets

SLR residuals for satellite SVN 736 (R09/R16)

Orbits are based on a three-day long-arc solutions.
Applying the estimated satellite antenna offsets

SLR residuals for satellite SVN 737 (R12)

Orbits are based on a three-day long-arc solutions.
Applying the estimated satellite antenna offsets

SLR residuals for satellite SVN 737 (R12)

Orbits are based on a three-day long-arc solutions.
Applying the estimated satellite antenna offsets

SLR residuals for satellite SVN 735 (R05)

Orbits are based on a three-day long-arc solutions.
Applying the estimated satellite antenna offsets

SLR residuals for satellite SVN 735 (R05)

Orbits are based on a three-day long-arc solutions.
Applying the estimated satellite antenna offsets

Quantile 25%, 50%, and 75% of SLR residuals per year in mm

- using original estimated SAOs
- sat. 715
- sat. 716
- sat. 717
- sat. 719
- sat. 721
- sat. 723

Year
Applying the estimated satellite antenna offsets

Quantile 25%, 50%, and 75% of SLR residuals per year in mm

Using original estimated SAOs

sat. 725

sat. 728

sat. 730

sat. 732

sat. 734

sat. 735

Year


Astronomical Institute, University of Bern
Applying the estimated satellite antenna offsets

Quantile 25%, 50%, and 75% of SLR residuals per year in mm

Orbits are based on a three-day long-arc solutions.
Discussion and summary

What could be the reason at the spacecraft?

Shift of the center of mass:
If the satellite has roughly a mass of 1500 kg, 150 kg need to be shifted by 1 m in order to generate a COM shift of 10 cm.

http://spaceflight101.com/spacecraft/glonass-m/
Discussion and summary

What could be the reason at the spacecraft?

Issue with satellite antenna:
Not likely because SAO-Z is not affected in most cases and the SAO-X/Y estimates do not show a pattern

http://spaceflight101.com/spacecraft/glonass-m/
Discussion and summary

What could be the reason at the spacecraft?

Satellite attitude misorientation:
The satellite plane with the navigation antenna and the SLR reflector is about 2 m away from the center of mass.
A shift of 10 to 15 cm results in a tilt of the 3 to 4 degree of the satellite body.

http://spaceflight101.com/spacecraft/glonass-m/
Discussion and summary

What could be the reason at the spacecraft?

- **Shift of the center of mass:**
  
  If the satellite has roughly a mass of 1500 kg, 150 kg need to be shifted by 1 m in order to generate a COM shift of 10 cm.

- **Issue with satellite antenna:**
  
  Not likely because SAO-Z is not affected in most cases and the SAO-X/Y estimates do not show a pattern.

- **Satellite attitude misorientation:**
  
  The satellite plane with the navigation antenna and the SLR reflector is about 2 m away from the center of mass. A shift of 10 to 15 cm results in a tilt of the 3 to 4 degree of the satellite body.
Discussion and summary

What could be the reason at the spacecraft?

- Shift of the center of mass:
  If the satellite has roughly a mass of 1500 kg, 150 kg need to be shifted by 1 m in order to generate a COM shift of 10 cm.

- Issue with satellite antenna:
  Not likely because SAO-Z is not affected in most cases and the SAO-X/Y estimates do not show a pattern

- Satellite attitude misorientation:
  The satellite plane with the navigation antenna and the SLR reflector is about 2 m away from the center of mass.
  A shift of 10 to 15 cm results in a tilt of the 3 to 4 degree of the satellite body.

The usage of the estimated SAOs obviously helps to reduce the SLR residuals.
# List of estimated satellite antenna offsets

<table>
<thead>
<tr>
<th>Satellite</th>
<th>from</th>
<th>to</th>
<th>$\Delta X$</th>
<th>$\Delta Y$</th>
<th>SAO-X</th>
<th>SAO-Y</th>
<th>Satellite type</th>
</tr>
</thead>
<tbody>
<tr>
<td>701</td>
<td>R06 2008 04 27 00 00 00</td>
<td>2009 06 16 23 59 59</td>
<td>-0.1240</td>
<td>0.0037</td>
<td>-0.6691</td>
<td>0.0037</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>713</td>
<td>R24 2005 12 25 00 00 00</td>
<td>2010 02 28 23 59 59</td>
<td>-0.0507</td>
<td>-0.0412</td>
<td>-0.5957</td>
<td>-0.0412</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>714</td>
<td>R06 2010 04 28 00 00 00</td>
<td>2010 09 30 23 59 59</td>
<td>0.1507</td>
<td>-0.0586</td>
<td>-0.3943</td>
<td>-0.0586</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>714</td>
<td>R17 2010 12 16 00 00 00</td>
<td>2010 03 18 23 59 59</td>
<td>0.1507</td>
<td>-0.0586</td>
<td>-0.3943</td>
<td>-0.0586</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>715</td>
<td>R03 2011 10 02 00 00 00</td>
<td>2013 03 06 23 59 59</td>
<td>0.0016</td>
<td>-0.0772</td>
<td>-0.5434</td>
<td>-0.0772</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>715</td>
<td>R14 2013 03 07 00 00 00</td>
<td>2013</td>
<td>0.0319</td>
<td>-0.1560</td>
<td>-0.5131</td>
<td>-0.1560</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>716</td>
<td>R15 2006 12 25 00 00 00</td>
<td>2008</td>
<td>0.0387</td>
<td>0.0479</td>
<td>-0.5063</td>
<td>0.0479</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>717</td>
<td>R10 2006 12 25 00 00 00</td>
<td>2009</td>
<td>0.0488</td>
<td>-0.0127</td>
<td>-0.4962</td>
<td>-0.0127</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>718</td>
<td>R17 2007 10 26 00 00 00</td>
<td>2010 12 15 23 59 59</td>
<td>0.0454</td>
<td>-0.0505</td>
<td>-0.4996</td>
<td>-0.0505</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>719</td>
<td>R20 2007 10 26 00 00 00</td>
<td>2011 03 05 23 59 59</td>
<td>-0.0660</td>
<td>0.0504</td>
<td>-0.6110</td>
<td>0.0504</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>719</td>
<td>R20 2011 03 06 00 00 00</td>
<td>2013</td>
<td>-0.0128</td>
<td>0.1329</td>
<td>-0.5578</td>
<td>0.1329</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>721</td>
<td>R13 2013 10 20 00 00 00</td>
<td>2015 01 17 23 59 59</td>
<td>-0.0533</td>
<td>0.0712</td>
<td>-0.5983</td>
<td>0.0712</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>722</td>
<td>R09 2007 12 25 00 00 00</td>
<td>2010 09 30 23 59 59</td>
<td>-0.0354</td>
<td>-0.0144</td>
<td>-0.5804</td>
<td>-0.0144</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>723</td>
<td>R11 2007 12 25 00 00 00</td>
<td>2010 07 17 23 59 59</td>
<td>-0.0550</td>
<td>0.0049</td>
<td>-0.6000</td>
<td>0.0049</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>723</td>
<td>R11 2010 07 18 00 00 00</td>
<td>2016 03 02 23 59 59</td>
<td>-0.1222</td>
<td>0.0457</td>
<td>-0.6672</td>
<td>0.0457</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>725</td>
<td>R21 2011 11 06 00 00 00</td>
<td>2014 07 31 23 59 59</td>
<td>-0.1002</td>
<td>0.0144</td>
<td>-0.6452</td>
<td>0.0144</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>726</td>
<td>R22 2008 09 25 00 00 00</td>
<td>2010 02 28 23 59 59</td>
<td>-0.0343</td>
<td>-0.0050</td>
<td>-0.5793</td>
<td>-0.0050</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>728</td>
<td>R02 2012 05 06 00 00 00</td>
<td>2013 06 29 23 59 59</td>
<td>-0.0523</td>
<td>-0.0077</td>
<td>-0.5973</td>
<td>-0.0077</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>730</td>
<td>R01 2009 12 14 00 00 00</td>
<td>2010 12 18 23 59 59</td>
<td>0.0396</td>
<td>0.0073</td>
<td>-0.5054</td>
<td>0.0073</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>730</td>
<td>R01 2010 12 19 00 00 00</td>
<td>2012 07 14 23 59 59</td>
<td>0.0688</td>
<td>0.0121</td>
<td>-0.4762</td>
<td>0.0121</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>Satellite</td>
<td>from</td>
<td>to</td>
<td>∆X</td>
<td>∆Y</td>
<td>SAO-X</td>
<td>SAO-Y</td>
<td>Satellite type</td>
</tr>
<tr>
<td>-----------</td>
<td>------</td>
<td>----</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
<td>----------------</td>
</tr>
<tr>
<td>730</td>
<td>R01</td>
<td>2012 07 15 00 00 00</td>
<td>-0.0694</td>
<td>0.0184</td>
<td>-0.6144</td>
<td>0.0184</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>732</td>
<td>R23</td>
<td>2015 02 01 00 00 00</td>
<td>0.0753</td>
<td>-0.0130</td>
<td>-0.4697</td>
<td>-0.0131</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>734</td>
<td>R05</td>
<td>2015 02 01 00 00 00</td>
<td>-0.0009</td>
<td>-0.1437</td>
<td>-0.5459</td>
<td>-0.1437</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>735</td>
<td>R24</td>
<td>2015 04 12 00 00 00</td>
<td>0.0329</td>
<td>0.1116</td>
<td>-0.5121</td>
<td>0.1116</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>736</td>
<td>R09</td>
<td>2013 12 08 00 00 00</td>
<td>0.1589</td>
<td>-0.0166</td>
<td>-0.3861</td>
<td>-0.0166</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>736</td>
<td>R09</td>
<td>2015 03 08 00 00 00</td>
<td>0.0554</td>
<td>-0.1265</td>
<td>-0.4896</td>
<td>-0.1265</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>736</td>
<td>R16</td>
<td>2016 03 07 00 00 00</td>
<td>0.0192</td>
<td>-0.1335</td>
<td>-0.5258</td>
<td>-0.1335</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>736</td>
<td>R12</td>
<td>2013 12 08 00 00 00</td>
<td>-0.1254</td>
<td>-0.0149</td>
<td>-0.6704</td>
<td>-0.0149</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>737</td>
<td>R12</td>
<td>2015 12 27 00 00 00</td>
<td>-0.0814</td>
<td>0.0252</td>
<td>-0.6264</td>
<td>0.0252</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>738</td>
<td>R16</td>
<td>2012 12 16 00 00 00</td>
<td>0.0434</td>
<td>-0.0545</td>
<td>-0.5016</td>
<td>-0.0545</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>744</td>
<td>R03</td>
<td>2011 12 01 00 00 00</td>
<td>0.0285</td>
<td>-0.0440</td>
<td>-0.5165</td>
<td>-0.0440</td>
<td>GLONASS-M</td>
</tr>
<tr>
<td>779</td>
<td>R01</td>
<td>1999 01 01 00 00 00</td>
<td>0.0936</td>
<td>-0.0116</td>
<td>0.0936</td>
<td>-0.0116</td>
<td>GLONASS</td>
</tr>
<tr>
<td>783</td>
<td>R18</td>
<td>2000 10 13 00 00 00</td>
<td>-0.0600</td>
<td>0.0330</td>
<td>-0.0600</td>
<td>0.0330</td>
<td>GLONASS</td>
</tr>
<tr>
<td>783</td>
<td>R18</td>
<td>2004 06 27 00 00 00</td>
<td>-0.0914</td>
<td>0.1064</td>
<td>-0.0914</td>
<td>0.1064</td>
<td>GLONASS</td>
</tr>
<tr>
<td>788</td>
<td>R24</td>
<td>2003 09 07 00 00 00</td>
<td>-0.0345</td>
<td>0.0698</td>
<td>-0.0345</td>
<td>0.0698</td>
<td>GLONASS</td>
</tr>
<tr>
<td>789</td>
<td>R03</td>
<td>2001 12 01 00 00 00</td>
<td>-0.0149</td>
<td>0.0308</td>
<td>-0.0149</td>
<td>0.0308</td>
<td>GLONASS</td>
</tr>
<tr>
<td>791</td>
<td>R22</td>
<td>2002 12 25 00 00 00</td>
<td>-0.0247</td>
<td>-0.0482</td>
<td>-0.0247</td>
<td>-0.0482</td>
<td>GLONASS</td>
</tr>
<tr>
<td>792</td>
<td>R21</td>
<td>2006 05 21 00 00 00</td>
<td>-0.0626</td>
<td>0.0083</td>
<td>-0.0626</td>
<td>0.0083</td>
<td>GLONASS</td>
</tr>
<tr>
<td>796</td>
<td>R01</td>
<td>2004 12 26 00 00 00</td>
<td>-0.0352</td>
<td>-0.0035</td>
<td>-0.0352</td>
<td>-0.0035</td>
<td>GLONASS</td>
</tr>
<tr>
<td>798</td>
<td>R19</td>
<td>2005 12 25 00 00 00</td>
<td>-0.0675</td>
<td>0.0018</td>
<td>-0.0675</td>
<td>0.0018</td>
<td>GLONASS</td>
</tr>
</tbody>
</table>
THANK YOU for your attention

Publications of the satellite geodesy research group:
http://www.bernese.unibe.ch/publist