Session 1.2a  Strength, Weakness, Modeling Standards and Processing Strategies of Space Geodetic Techniques

Impact of GLONASS in a rigorous combination with GPS

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Outline

Observation data, modeling, processing scheme

Results from a combined GNSS processing

- Station coordinates/velocities
- Orbit validation
- Satellite clocks

Conclusions
Observation data and modeling

- Reprocessing starting on observation level: 1994 - 2011
- 340 GNSS stations in total (140 with GLONASS observation), 70 SLR stations
- GLONASS included since 01. January 2002
- GPS-only, GLONASS-only and GPS+GLONASS-combined solutions
- SLR: range residuals w.r.t. to microwave-based GNSS satellite orbits
- Processing of 24-hour epoch for clock solutions
- Major modelling aspects

  Terrestrial reference frame:  ITRF2008/IGS08
  GNSS antenna phase center:  IGS08.atx
  Atmospheric tidal loading:  $S_1+S_2$ tides (Ray and Ponte, 2003 )
  Atmospheric+oceanic non-tidal loading:  GRACE AOD1B (RL04)
  Radiation pressure for GNSS satellites:  Earth albedo included
Station network

- GPS+GLONASS
- GPS-only
- SLR
Number of processed stations and satellites

- GPS
- GPS+GLONASS
- GPS
- GLONASS
System-specific number of observation days

Relative contribution in terms of time series length

**Graphs:**

- **GPS**
  - Observation Time [years]
  - Number of Stations [%]
  - Observation Time [years]

- **GLONASS**
  - Observation Time [years]
  - Number of Stations [%]
**Terrestrial Reference Frame (TRF)**

<table>
<thead>
<tr>
<th>IGS08 w.r.t.</th>
<th>Translation [mm] / Translation rates [mm/y]</th>
<th>Scale [ppb]/ Scale rate [ppb/y]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
<td>Y</td>
</tr>
<tr>
<td>GPS-only</td>
<td>-4.3</td>
<td>-7.0</td>
</tr>
<tr>
<td></td>
<td>-1.1</td>
<td>+1.3</td>
</tr>
<tr>
<td>GPS+GLONASS</td>
<td>-4.1</td>
<td>-6.7</td>
</tr>
<tr>
<td></td>
<td>-1.0</td>
<td>+1.2</td>
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</tbody>
</table>
TRF: Time series analysis

**Input:** daily position time series

**Functional model:** annual, semi-annual, draconitic harmonics

**Stochastic model:** combined white + flicker noise model

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**GPS+GLONASS**  
(Vertical components)  
**GPS-only**

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![Graphs showing](image.png)
ORB: Transformation of satellite positions

1.9 cm (Earth albedo)
ORB: Overlaps from 1-day arcs

**GPS:**
- GPS-only
- GPS+GLONASS

**GLONASS:**
- GLONASS-only
- GPS+GLONASS
ORB: Overlaps from 3-day arcs

GPS:
- GPS-only
- GPS+GLONASS

GLONASS:
- GLONASS-only
- GPS+GLONASS
ORB: SLR range residuals

<table>
<thead>
<tr>
<th>GLONASS</th>
<th>GLONASS-M</th>
<th>GLONASS-M</th>
<th>GLONASS-K</th>
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</thead>
<tbody>
<tr>
<td>#4</td>
<td>#15</td>
<td>#8</td>
<td>#1</td>
</tr>
</tbody>
</table>

Mean bias [mm]

RMS [mm]

3-day arc

1-day arc

GPS+GLONASS

GLONASS-only
GNSS satellite clocks (30sec)

Modified Allan Deviation (MDEV) from a 5-day interval in 2008

**GPS**

\(\sim \tau^{-1/2}\)

\[\begin{align*}
10^{-12} & \\
10^{-13} & \\
10^{-14} & \\
10^{-15} & \\
\end{align*}\]

Averaging Interval \(\tau\) [s]

- BLOCK IIA
- BLOCK IIR

**GLONASS**

\(\sim \tau^{-1/2}\)

\[\begin{align*}
10^{-12} & \\
10^{-13} & \\
10^{-14} & \\
10^{-15} & \\
\end{align*}\]

Averaging Interval \(\tau\) [s]

- GLONASS
- GLONASS-M

(missing epochs < 5%)

(missing epochs < 15%)
PPP Phase Residuals
Conclusions

• Impact of including GLONASS on TRF parameters
  – no systematic effect for linear TRF parameters
  – slight reduction of daily position repeatabilities

• Combination with GPS and 3-day arc length significantly improves GLONASS orbits

• Conventional consideration of albedo modeling required

• Study of remaining model errors based on precise clocks products (yaw maneuvers modeling for both GNSS)
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