• SELenological and ENgineering Explorer
  • JAXA, 2007-2009
  • 3 lunar satellites

• same-beam differential VLBI (D-VLBI)
  • improved orbit consistency from several hundreds to several tens of metres [Goossens et al., 2010]

• nominal accuracy
  (differential phase delay rms):
  • 3.44 ps (1 mm) S-band
  [Kikuchi et al., 2009]

\[ \Delta \tau = \tau_{RSTAR} - \tau_{VSTAR} \]
• 2 datasets (from NAOJ Mizusawa):
  • October 2008, 17-22: 4 japanese antennas
  • January 2008, 12-16: 4 japanese antennas + intercontinental baselines
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  • Relativistic time and coordinate transformations (TDB, TT, TCB, TCG resp. BDRS, TRS, BCRS, GCRS)
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• Good agreement of 3 models (< 1 ps resp. < 3 ps)
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  • Klioner 1991
Delay model

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Differences correspond to the theoretical values

Verification through comparison of 3 models
10 mm ↔ 33 ps residuals o-c

\[ \Delta \tau = \tau_{RSTAR} - \tau_{VSTAR} \]
10 mm $\leftrightarrow$ 33 ps residuals o-c

$\Delta \tau = \tau_{RSTAR} - \tau_{VSTAR}$

JAN08 residuals obs-com after baseline offset
• Residuals are at the same level as those from NAOJ ± 10 mm (30 ps)

• NAOJ explains residuals with "probably mismodelling of solar radiation pressure"
### level of cancellation

<table>
<thead>
<tr>
<th>(long baselines)</th>
<th>$\tau$</th>
<th>$\Delta \tau$</th>
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<tr>
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- dUT1: 5 ms
- xp, yp: 200 mas
- dX, dY: 300 mas
## Level of cancellation

### (long baselines)

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**GEOMETRY:**

- **Antenna $\pm$ 5cm:** 300 ps, 1-2 ps
- **Orbit $\pm$ 10 m:** 150 -1000 ps, 2-8 ps
- **EOP:** 5 ps (60 ps), < 0.05 (0.1) ps
  - dUT1: 5 ms
  - xp, yp: 200 mas
  - dX, dY: 300 mas

**Usual elev > 20° min. elev. 10° (5°)**

### ATMOSPHERE:

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<tr>
<td>Trop_hydr</td>
<td>2-20 (10-60) ns</td>
<td>30-300 (50-1000) ps</td>
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<td>a priori</td>
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<tr>
<td>Trop_wet</td>
<td>1-3 (4) ns</td>
<td>4-40 (10-60) ps</td>
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<td>ECMWF</td>
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</tr>
<tr>
<td>Ionosphere</td>
<td>1.5 (2-10) ns</td>
<td>10 (80) ps</td>
</tr>
<tr>
<td>TEC-maps</td>
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**Peak at noon; nearly all observations during the night**
Ionosphere

OCT08 residual ionosphere

separation angle

elevation angle

[C. Tierno Ros]
simulated turbulence

VieVS-simulator [Pany et al., 2010]; N = 30
simulated turbulence

VieVS-simulator [Pany et al., 2010]; N = 30
VieVS-simulator [Pany et al., 2010]; N = 30

JAN08 simulated residual turbulence

Very low elevation (5°)
• Geometric effects (station coordinates, source coordinates, EOP) are nearly cancelled out.

• Residual tropospheric effects can reach the level of significance.
  • Particularly for intercontinental baselines.

• But: Applying wet troposphere and ionospheric corrections doesn‘t improve the result significantly.
  • Some residuals decrease but some others increase.
\[ \Delta \tau = \tau_{RSTAR} - \tau_{VSTAR} = \\
= [(RSTAR - St1) - (RSTAR - St2)] - [(VSTAR - St1) - (VSTAR - St2)] \\
\frac{\partial \Delta \tau}{\partial VSTAR} = -\frac{VSTAR - St1}{r_{VSTAR-St1}} + \frac{VSTAR - St2}{r_{VSTAR-St2}} \]
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\[ \Delta r = 0 \]

1 ps noise: OCT08: ± 100 m
JAN08: ± 50 m

implement condition \( \Delta r = 0 \)
• Model for orbit estimation (xyz) is correct, but highly correlated and unstable.

• Possible solution: $\Delta r = 0$

• NAOJ: total orbit errors at an average level of 18m

• Estimates: several km $\rightarrow$ some m

• Goal: find better strategies
  • Line of sight
  • estimate orbit parameters

• Upcoming: Studying estimation strategy with VLBI observations to GNSS-satellites.
References:


Pany et al., 2010: *Monte Carlo simulations of the impact of troposphere, clocks and measurement errors on the repeatability of VLBI positions*, J. of Geodesy, DOI: 10.1007/s00190-010-0415-1.