TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

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Session 3

Processing SELENE Differential VLBI Data

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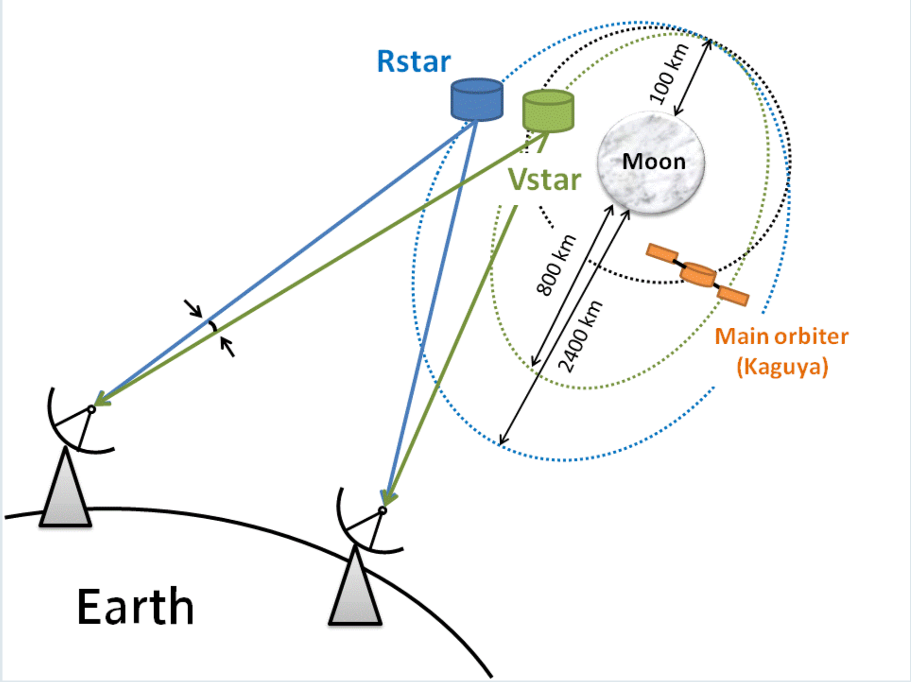
SELENE

- 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]

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



data

- 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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delay model

- Implementation into VieVS
- Challenges:
  - *Moving* sources at *finite distance*
  - Relativistic time and coordinate transformations (TDB, TT, TCB, TCG resp. BDRS, TRS, BCRS, GCRS)
  - Consistent application of corresponding scaling factors (Lc, Lg, Lb)
- Good agreement of 3 models (< 1 ps resp. < 3 ps)
  - Sekido & Fukushima 2006
  - Fukushima 1994
  - Klioner 1991

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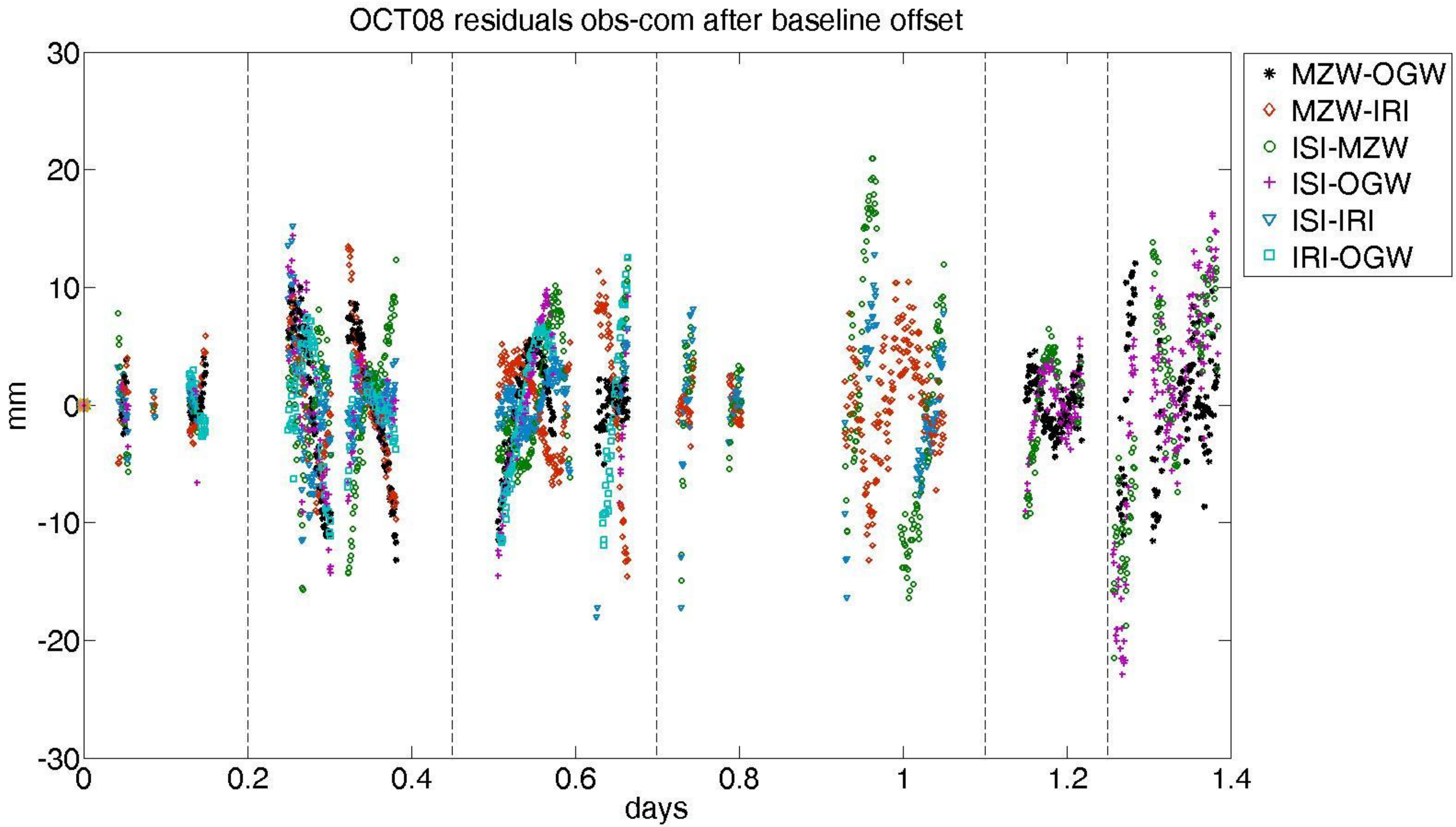
⇒ **Differences correspond to the theoretical values**

⇒ **Verification through comparison of 3 models**

10 mm ↔ 33 ps

residuals o-c



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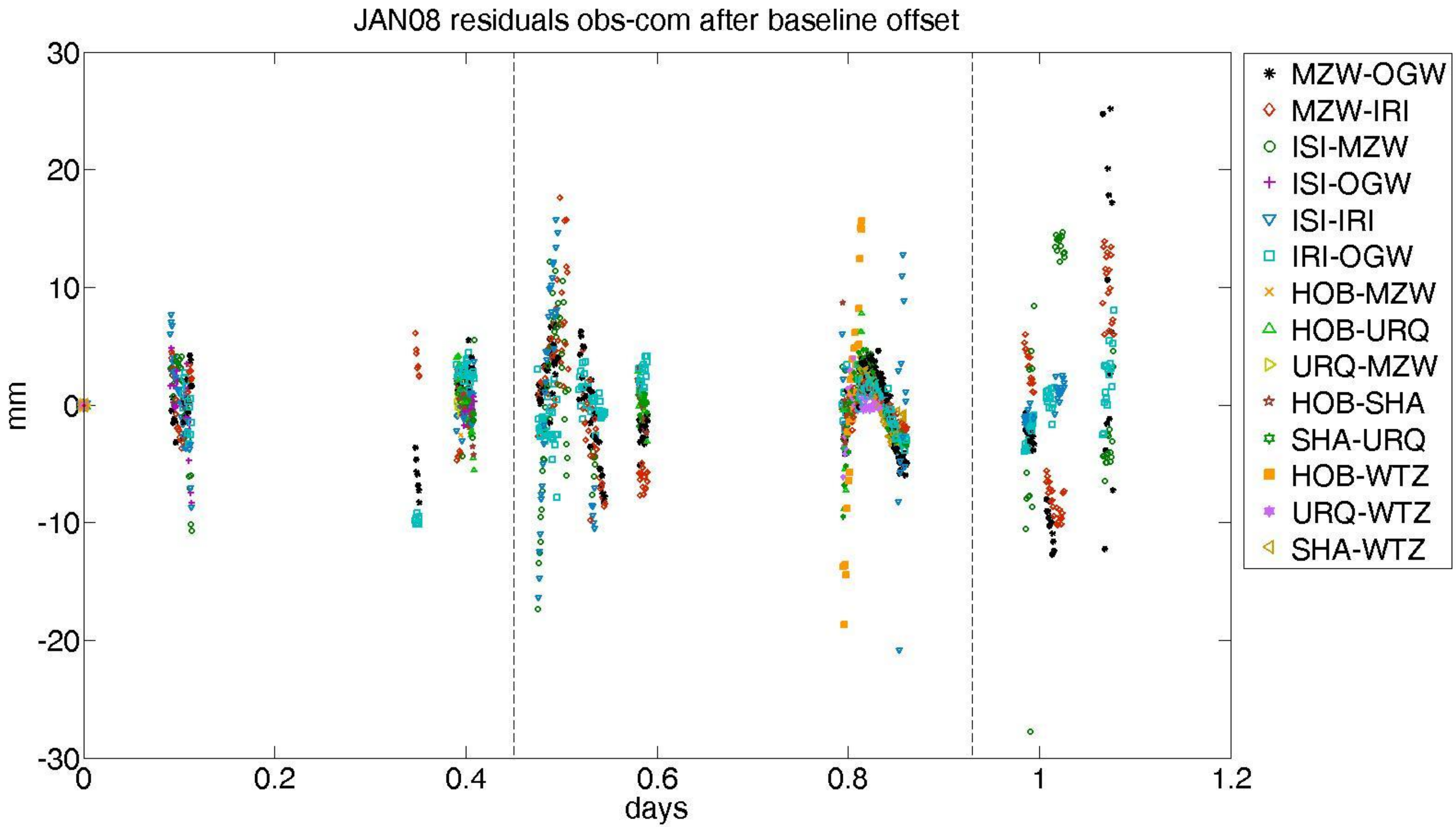

$$\Delta\tau = \tau_{RSTAR} - \tau_{VSTAR}$$

Results / Comparison

- 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

(long baselines)	τ	$\Delta\tau$
GEOMETRY:		
Antenna ± 5cm	**300 ps**	**1-2 ps**
Orbit ± 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

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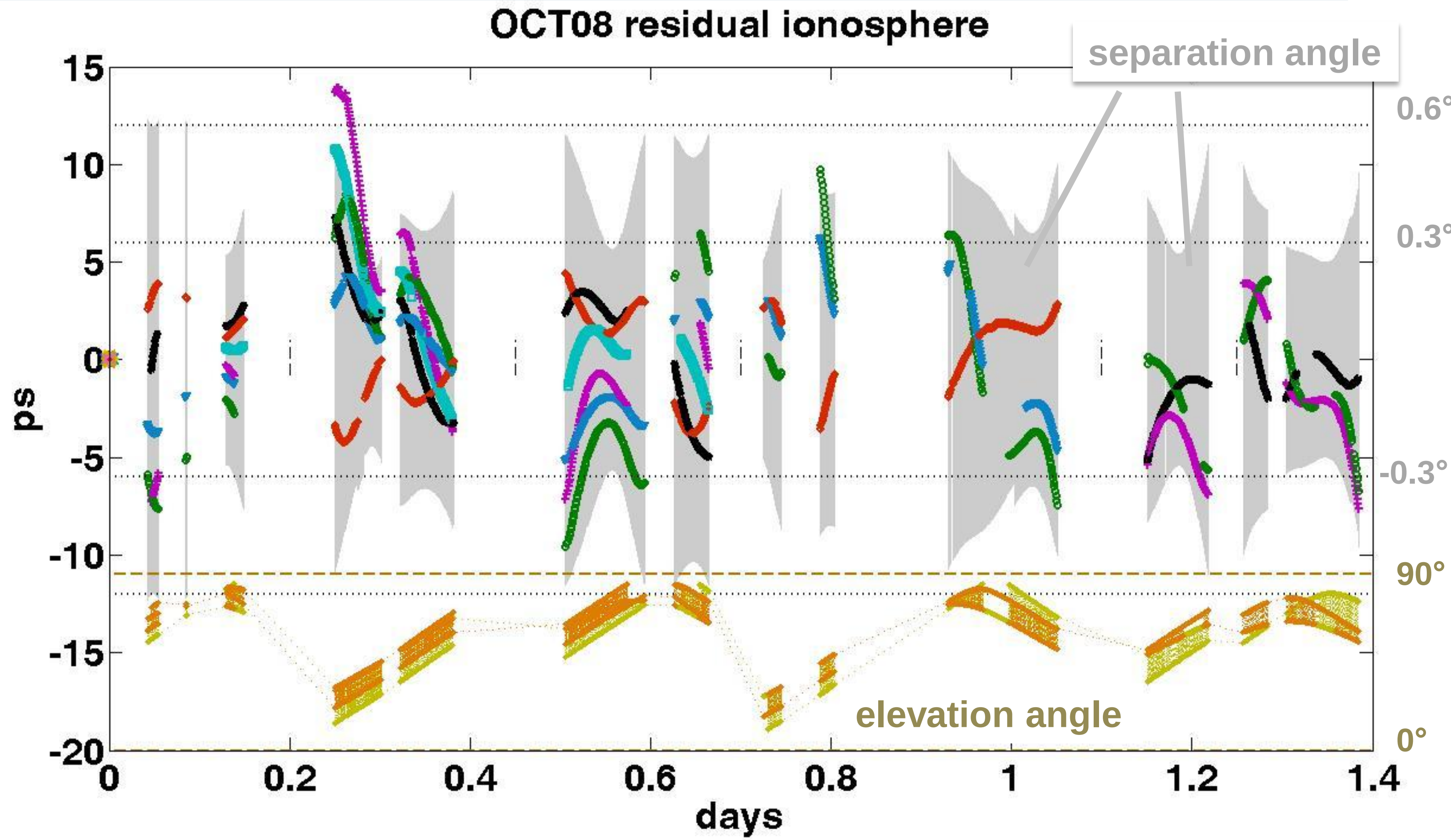
ATMOSPHERE:		
Trop_hydr	2-20 (10-60) ns	30-300 (50-1000) ps
a priori		
Trop_wet	1-3 (4) ns	4-40 (10-60) ps
ECMWF		
Ionosphere	1.5 (2-10) ns	10 (80) ps
TEC-maps		

usual elev > 20°
min. elev. 10° (5°)

Peak at noon; nearly all observations during the night

Ionosphere



[C. Tierno Ros]

simulated turbulence

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

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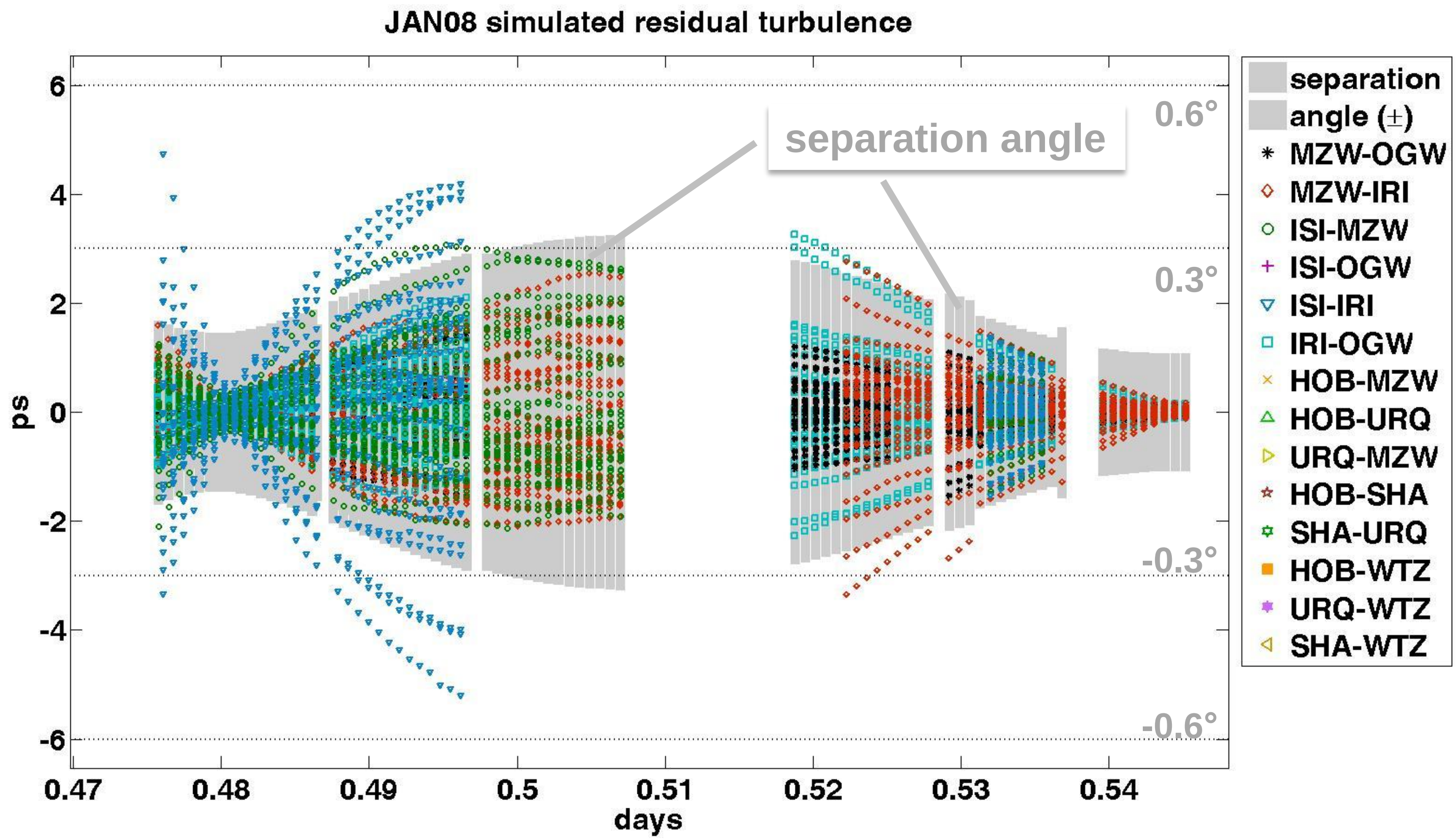
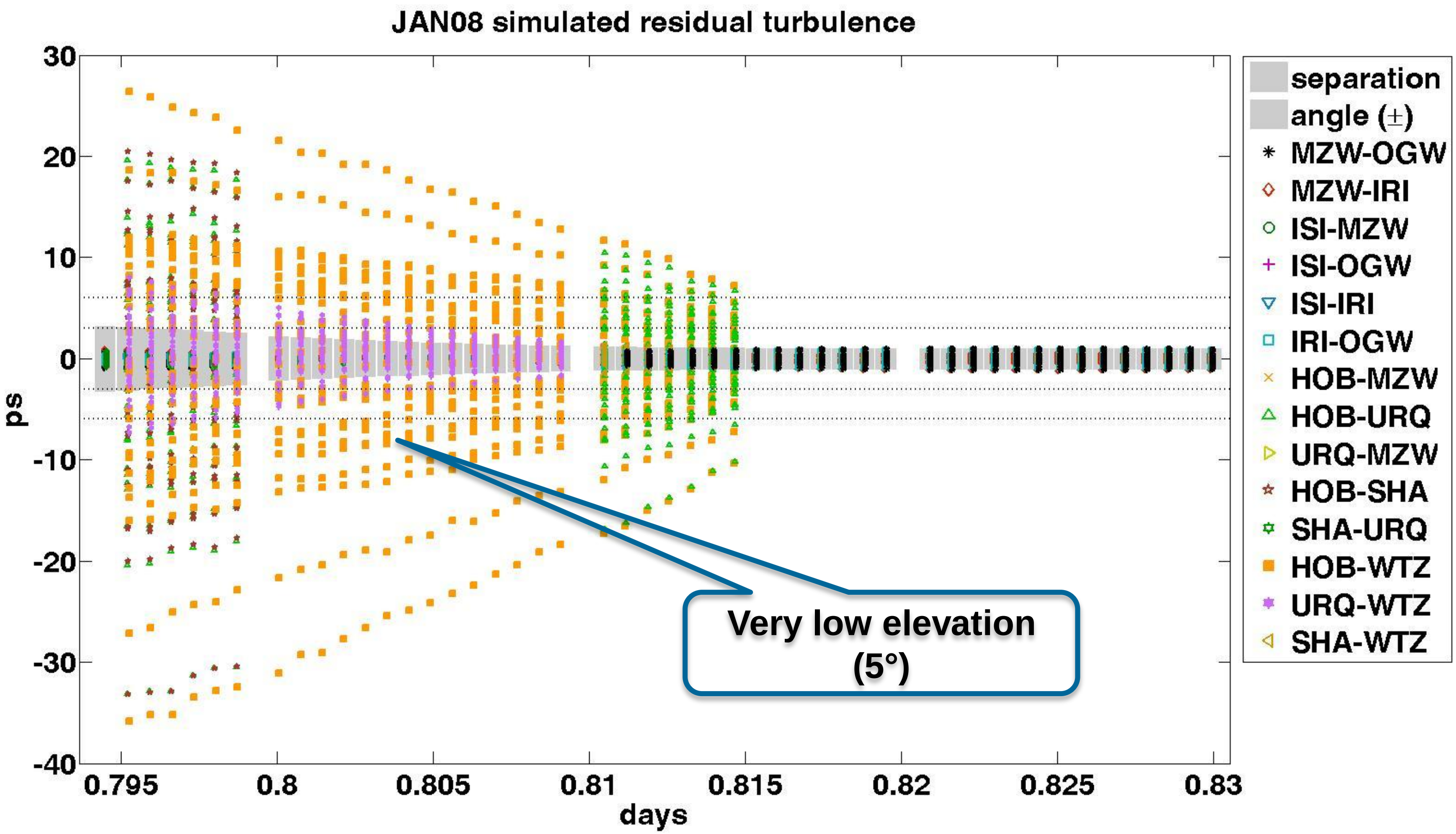


simulated turbulence

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



Results / Comparison (2)

- 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.*

orbit estimation

$$\Delta\tau = \tau_{RSTAR} - \tau_{VSTAR} =$$
$$= [(RSTAR - St1) - (RSTAR - St2)] - [(VSTAR - St1) - (VSTAR - St2)]$$

$$\frac{\partial \Delta\tau}{\partial VSTAR} = -\frac{VSTAR - St1}{r_{VSTAR-St1}} + \frac{VSTAR - St2}{r_{VSTAR-St2}}$$

orbit estimation

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$$= [(RSTAR - St1) - (RSTAR - St2)] - [(VSTAR - St1) - (VSTAR - St2)]$$

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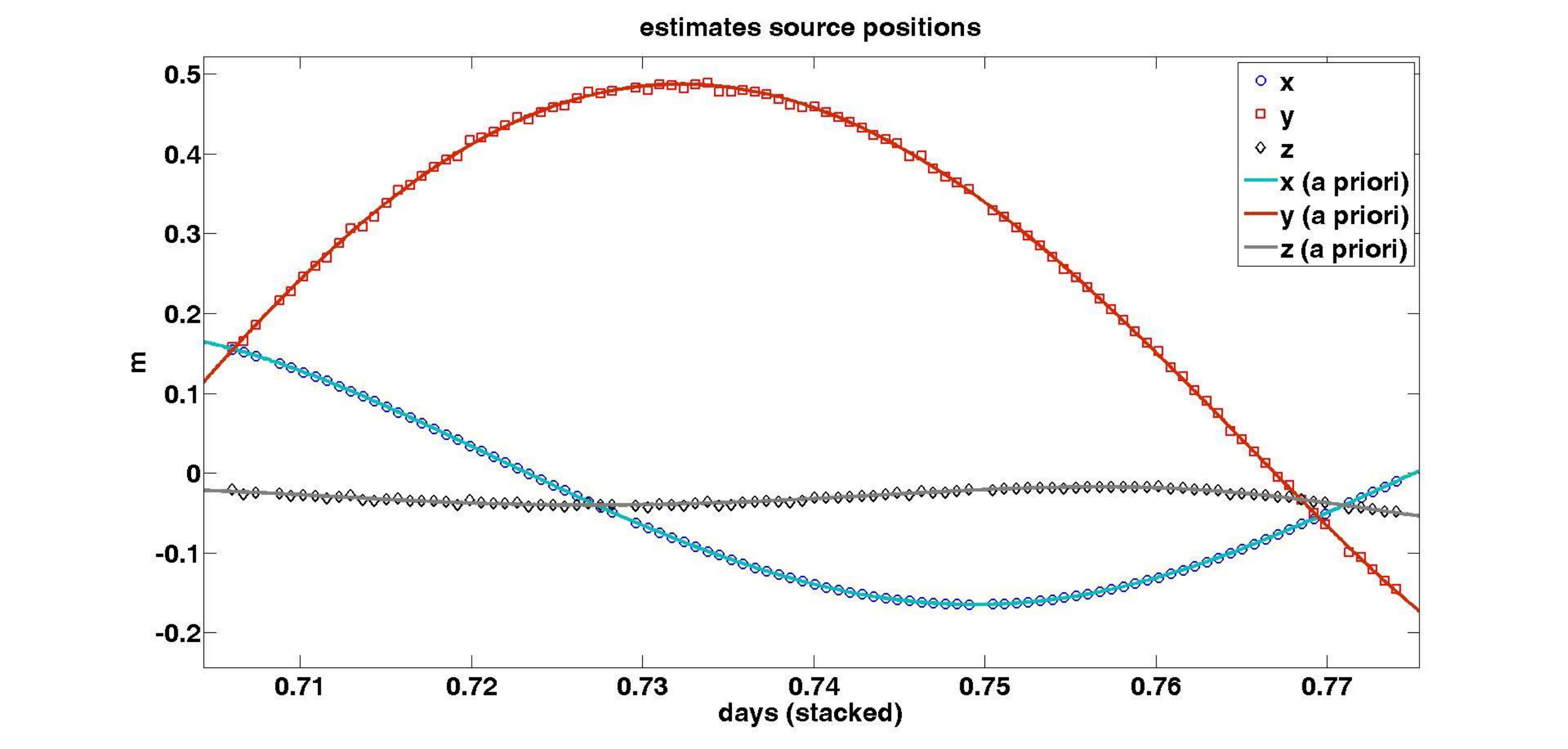
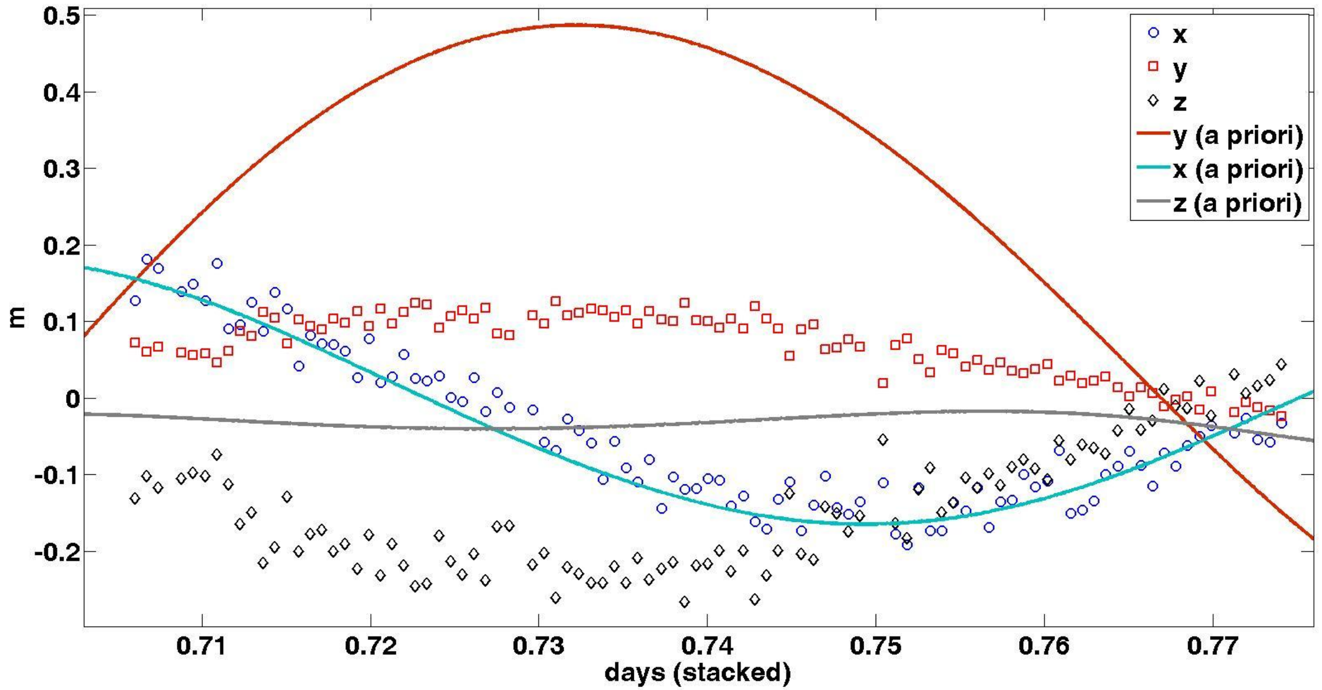


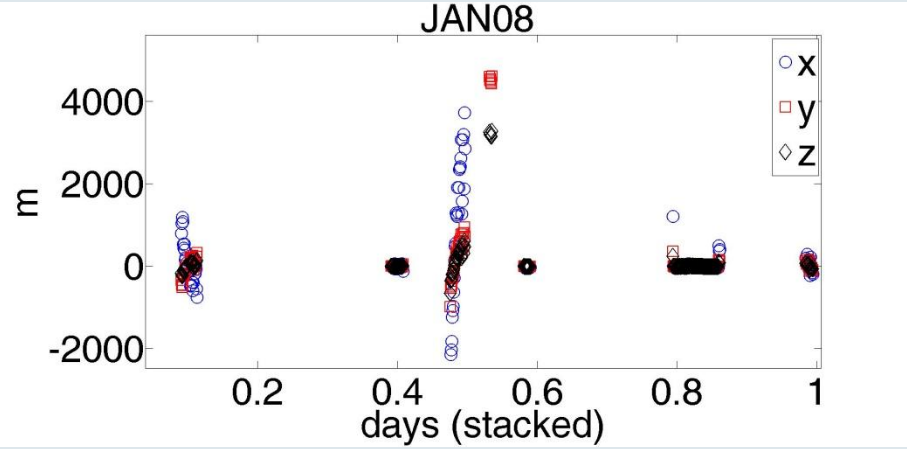
Δr = 0

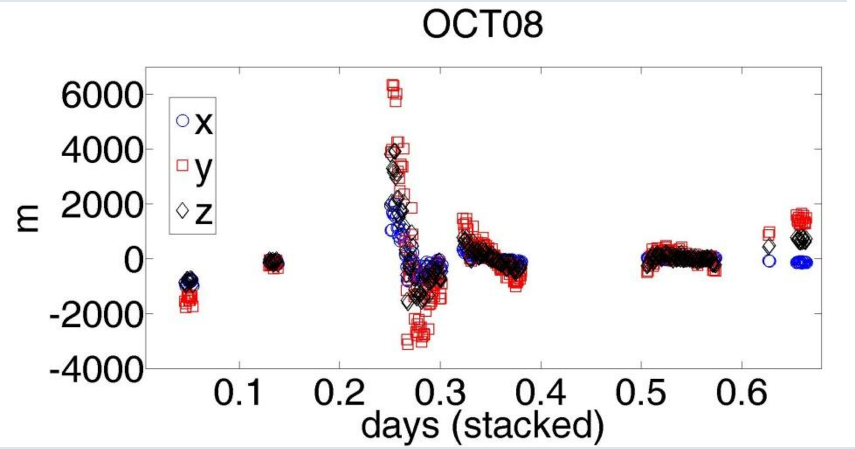
- **1 ps noise:** **OCT08:** **± 100 m**
  JAN08: **± 50 m**

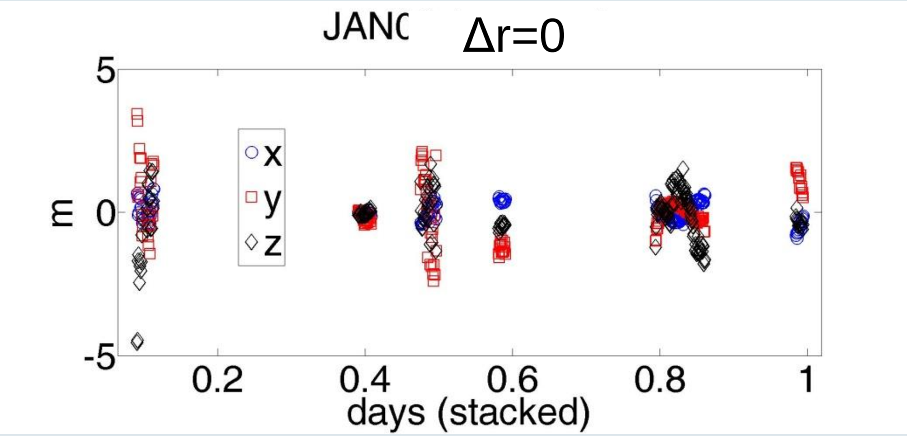
- **implement condition** Δr = 0

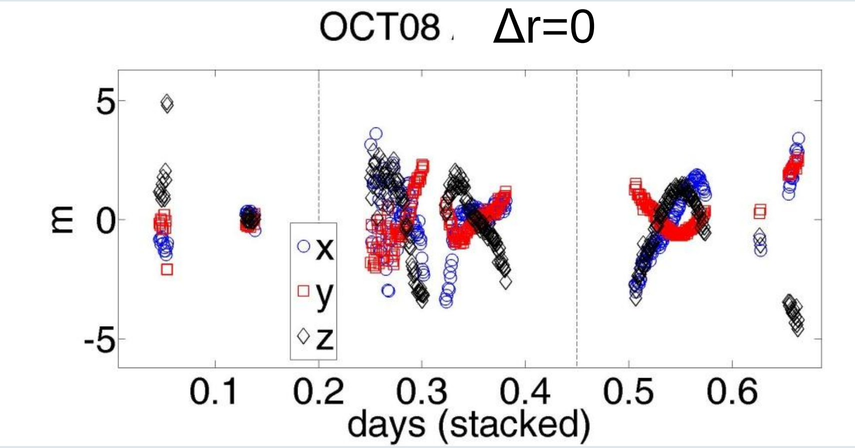


real data


JAN08
4000
2000
0
-2000
m
x
y
z
0.2
0.4
0.6
0.8
1
days (stacked)


OCT08
6000
4000
2000
0
-2000
-4000
m
x
y
z
0.1
0.2
0.3
0.4
0.5
0.6
days (stacked)


Δr=0
5
0
-5
m
x
y
z
0.2
0.4
0.6
0.8
1
days (stacked)


OCT08
Δr=0
5
0
-5
m
x
y
z
0.1
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0.6
days (stacked)

Results / Comparison (3)

- 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 → some m
- Goal: find better strategies
  - *Line of sight*
  - *estimate orbit parameters*
- **Upcoming: Studying estimation strategy with VLBI observations to GNSS-satellites.**

THE END

Thank You for listening!

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References:

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Kikuchi et al., 2009: *Pico-second accuracy VLBI of the two sub-satellites of SELENE (KAGUYA) using multi-frequency and same-beam methods*, Radio Sci. 44(RS2008).

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Sekido & Fukushima, 2006: *A VLBI delay model for radio sources at a finite distance,* J. of Geodesy, 80:137-149, DOI 10.1007/s00190-006-0035-y.

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.