TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

RESEARCH GROUP ADVANCED GEODESY
Institute of Geodesy and Geophysics

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Session 3

First steps of processing space VLBI data with VieVS

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Vienna VLBI Software

Space VLBI

- Space VLBI = VLBI with sources alternatively to quasars, mostly within the solar system
- e. g. differential VLBI (D-VLBI)
  - Spacecraft navigation (→ Ephemerides)
- Several new & interesting missions
  - NASA (DSN)
  - ESA (ΔDOR)
  - JAXA (Selene, Selene 2)
  - SHAO (Chang'e-1, Chang'e 2, YH Mars orbiter)
  - "VLBI transmitters" on satellites
- Opens up new possibilities for
  - Navigation
  - Frame ties
    - in space
    - between reference frames

Tasks – my task

1) **Specify system configuration**
   - Signal, frequency
   - Single vs. Differential

no

2) **Observe & correlate**
   - Solve ambiguities

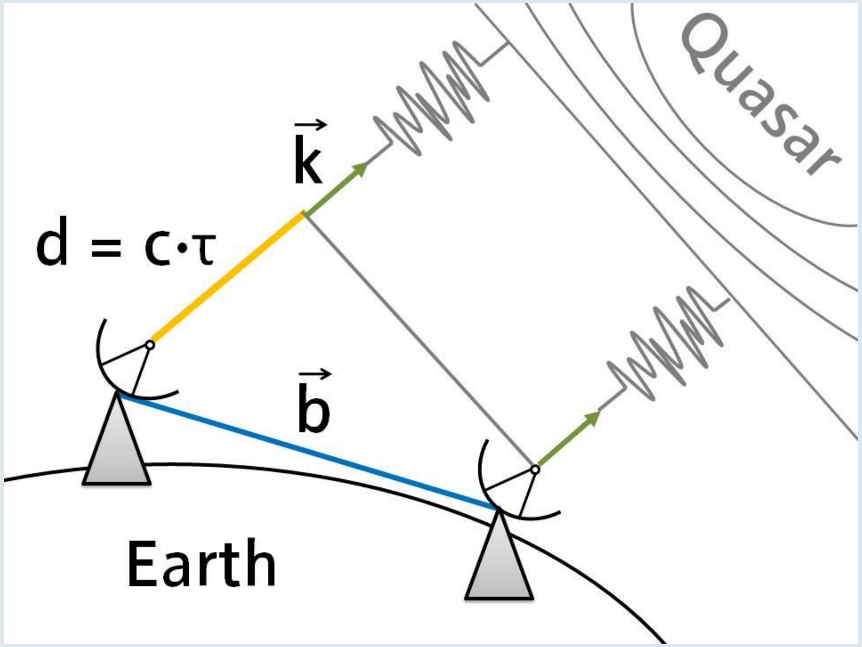
no

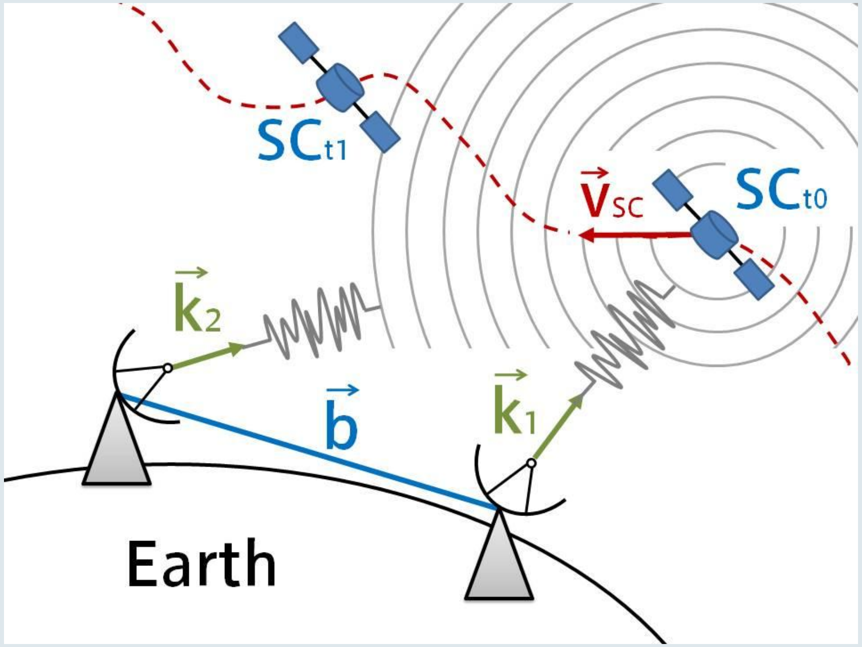
3) **Process**
   - Delay modelling
   - Realized in VieVS

yes

Geodetic vs. Space VLBI

GEODETIC VLBI	SPACE VLBI
• plane wave front	• curved wave front
• stable sources	• fast moving sources
	• time of emission t0





2 experiments

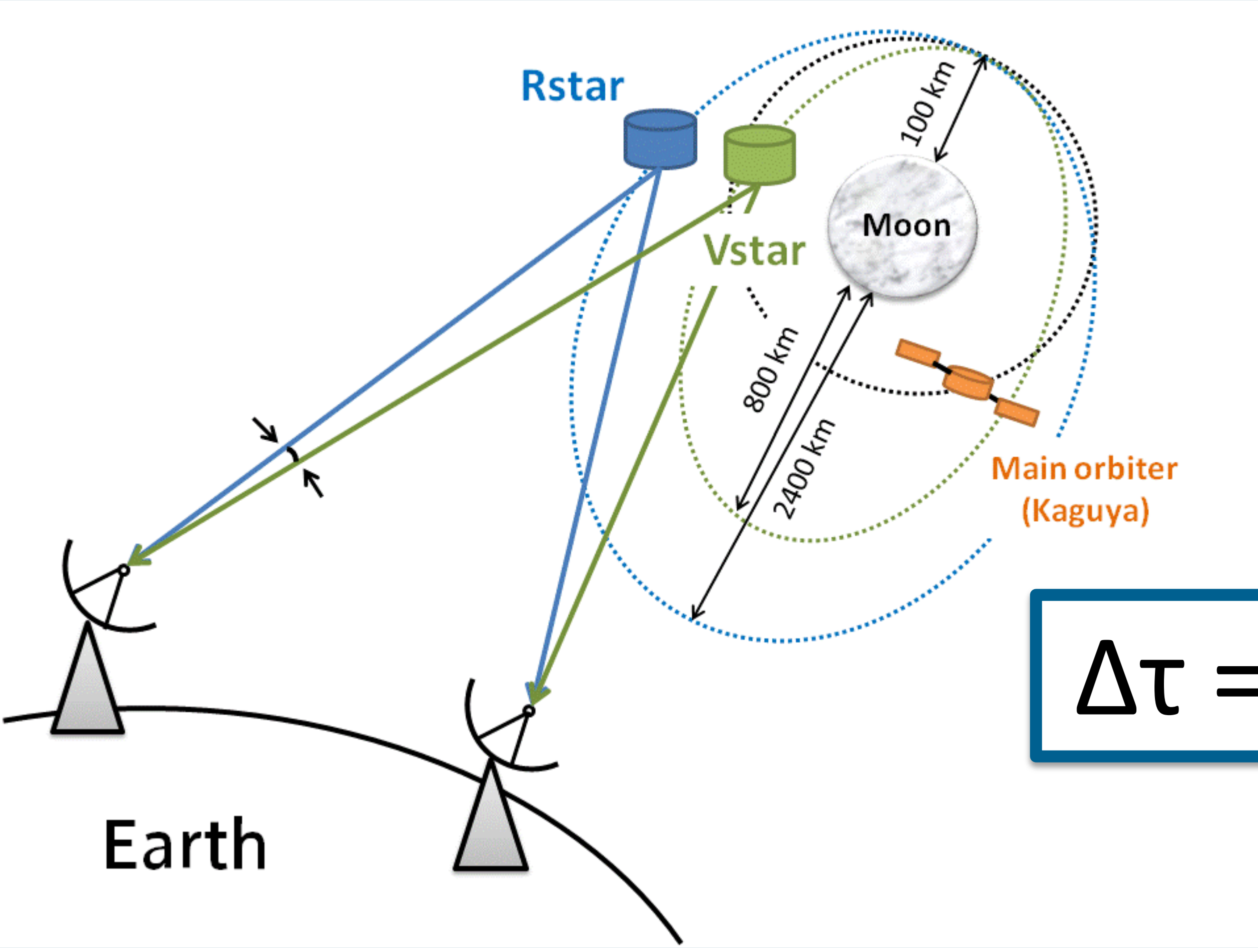
1

Same beam differential VLBI data from Selene

2

VLBI observations of GNNS satellites

1: D-VLBI data from Selene



- differential (D-) VLBI data
- same beam

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

- many effects are the same for τ_{RSTAR} and τ_{VSTAR}

1: D-VLBI delay model

Fukushima & Sekido, 2006:

“A VLBI delay model for radio sources at finite distance“

- Light time iteration

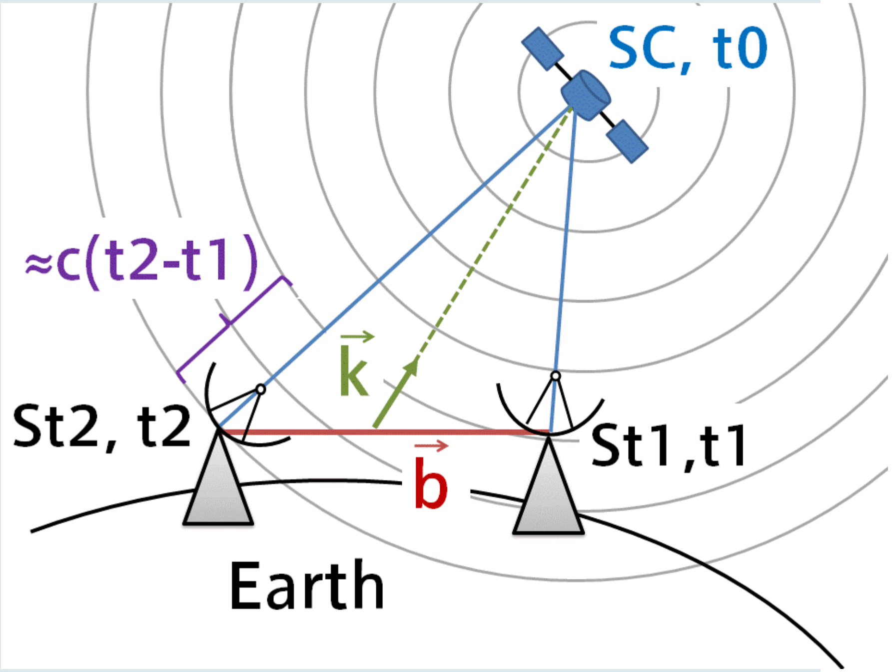
$$t_0(i+1) = t_0(i) - \frac{SC_{t0} - St1_{t1}}{c} - \tau_{grav}$$

- Pseudo direction vector

$$\vec{k} = \frac{\vec{R}_1(t_1) + \vec{R}_2(t_1)}{R_1(t_1) + R_2(t_1)}$$

- Correction term

$$\approx \vec{v}_2(t_2 - t_1)/c$$



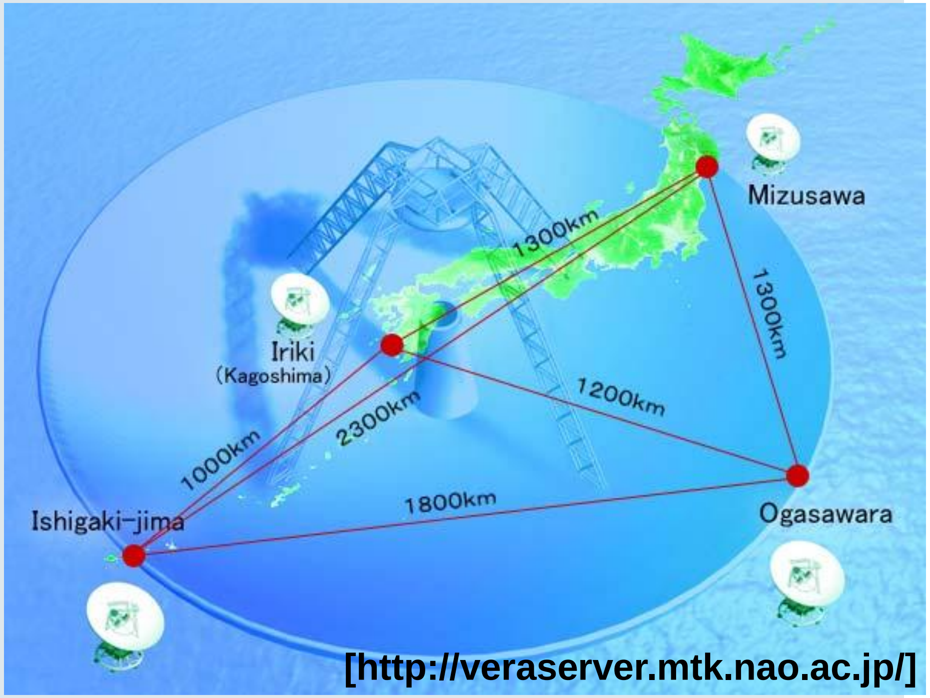
1: processed Selene data

- Selene same beam data is provided by RISE group at NAOJ Mizusawa
- Nominal accuracy (differential phase delay rms), [Kikuchi et al., 2009]:

  3.44 ps (1 mm) S-band
  0.64 ps (0.2 mm) X-band

- S-band same beam data from 4 VERA stations of October 19 2008, 17-19 UT

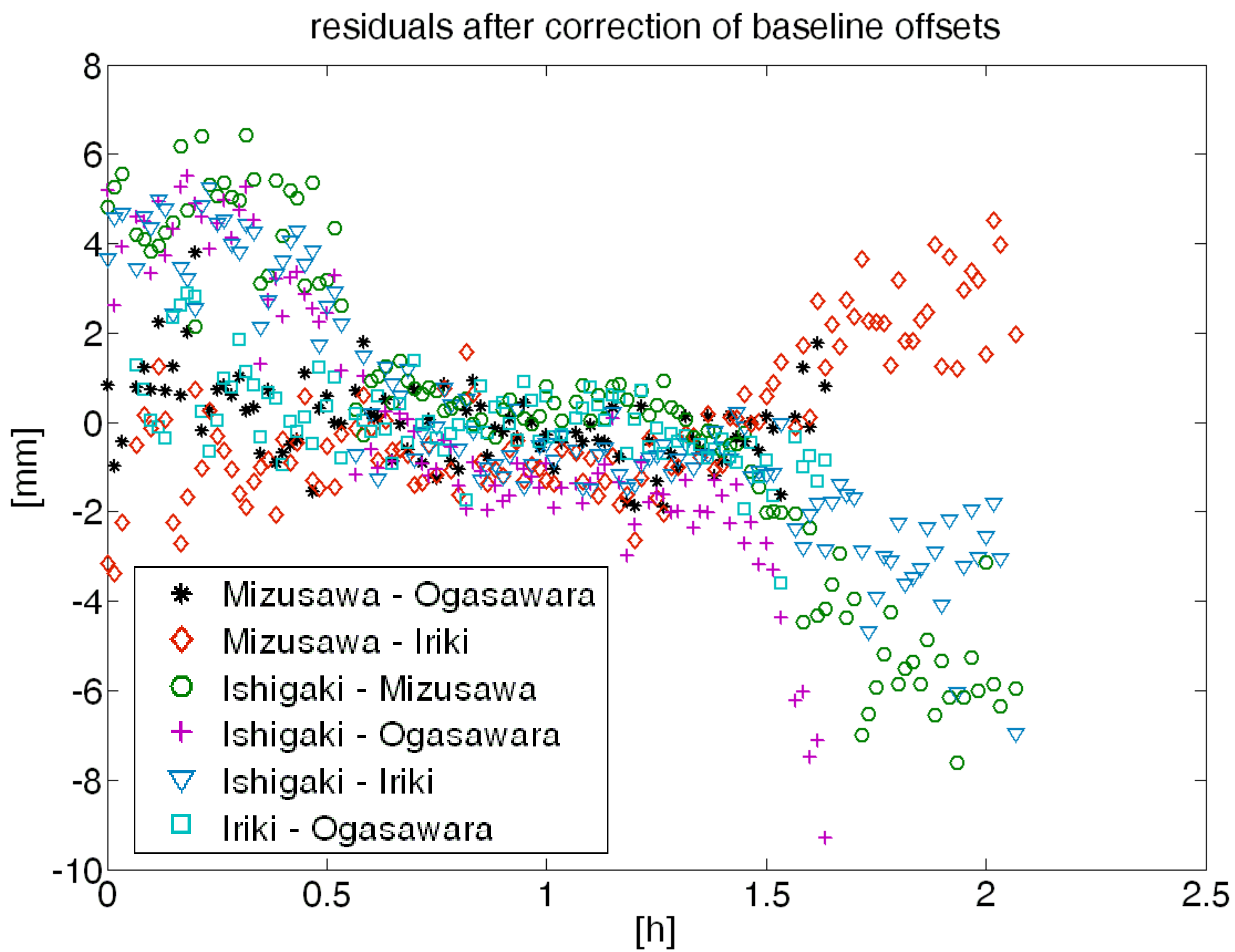
  Mizusawa,
  Iriki,
  Ishigaki,
  Ogasawara



[http://veraserver.mtk.nao.ac.jp/]

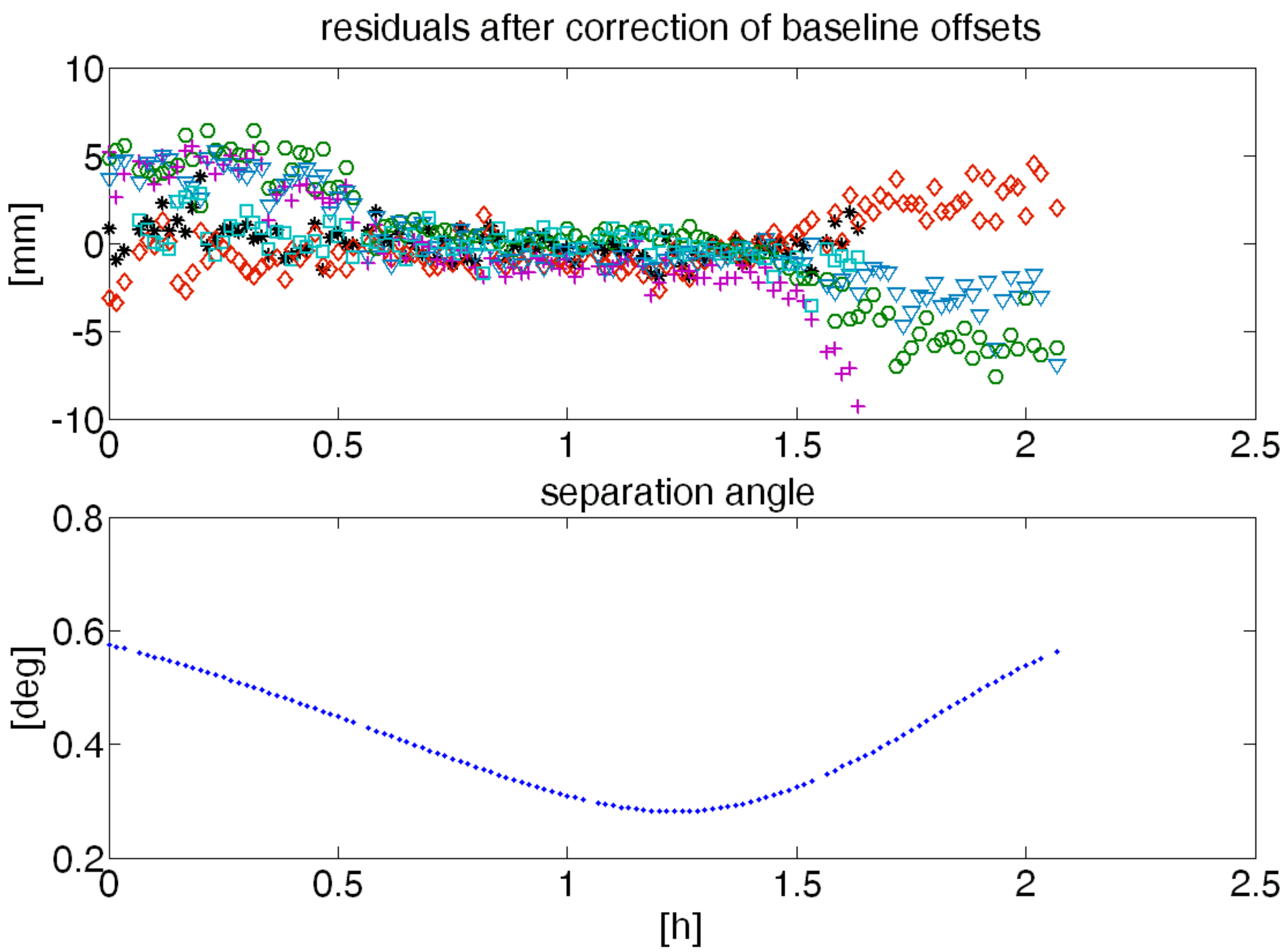
- Plottet residuals: Δτ observed-computed (6 baselines), 1 offset per baseline estimated

1: results



residuals after correction of baseline offsets
8
6
4
2
0
-2
-4
-6
-8
-10
[mm]
0
0.5
1
1.5
2
2.5
[h]
Mizusawa - Ogasawara
Mizusawa - Iriki
Ishigaki - Mizusawa
Ishigaki - Ogasawara
Ishigaki - Iriki
Iriki - Ogasawara

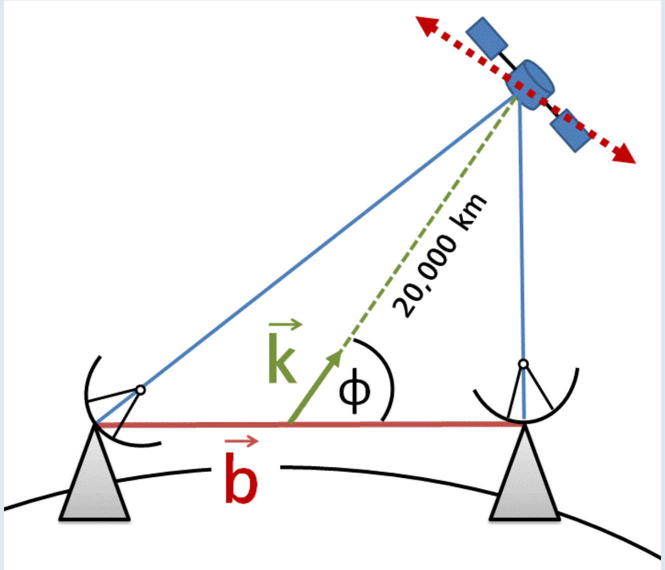
1: results


residuals after correction of baseline offsets
10
5
0
-5
-10
[mm]
0
0.5
1
1.5
2
2.5
separation angle
0.8
0.6
0.4
0.2
[deg]
0
0.5
1
1.5
2
2.5
[h]

2: GNSSVLBI

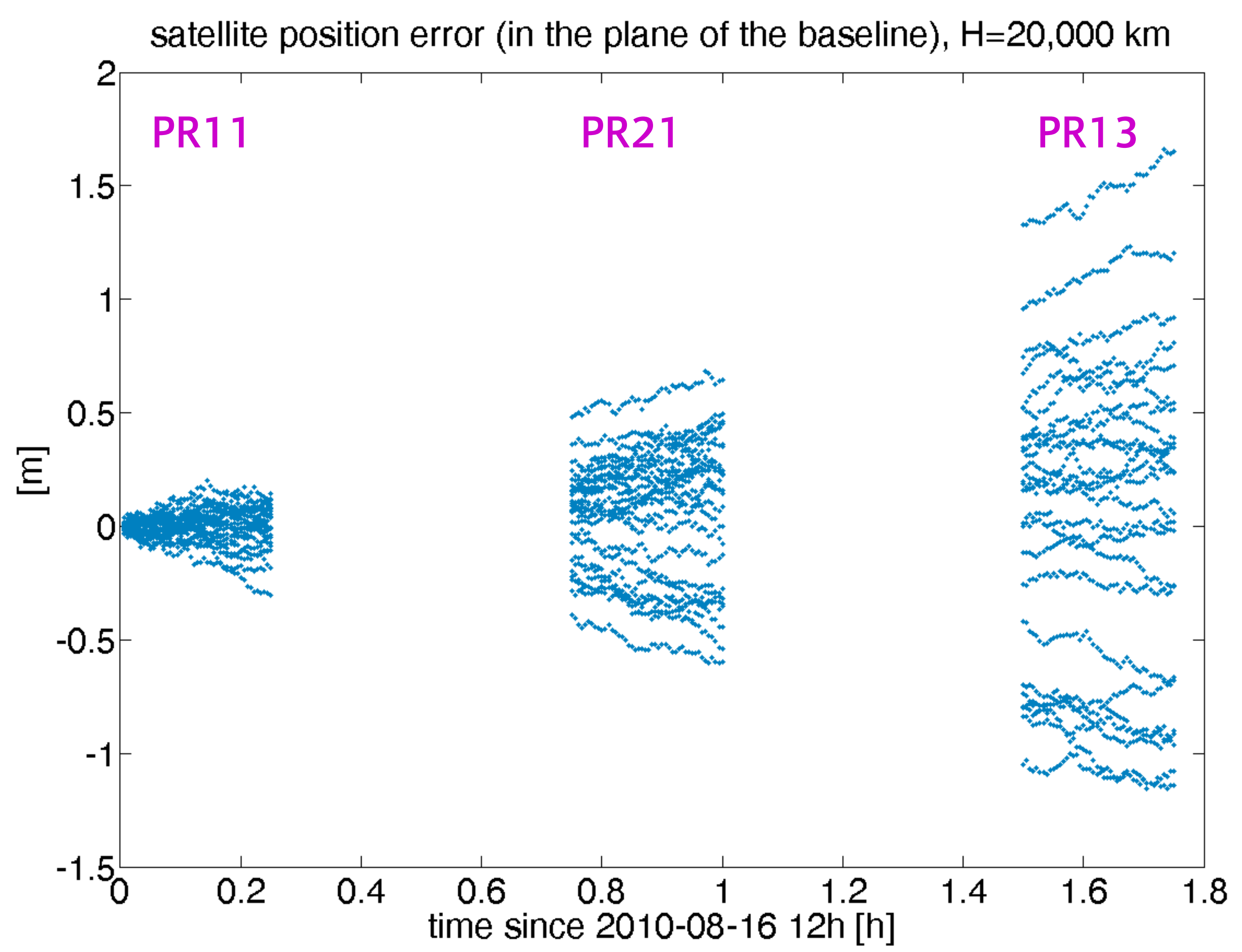
- Observe GLONASS satellites with VLBI
  - Tornatore et al., 2010
  - Single source VLBI
- Delay model:
  - Klioner, 1991
  - Everything is modelled in GCRS
- Simulations performed:
  - Vie_sim
    - Parameter: $\phi_0 + d\phi$
    - Partial: $d\tau / d\phi$
  - Experiment:

time:	2010 Aug 16
antennas:	Medicina, Onsala
sources:	GLONASS PR11, PR13, PR21
observations:	12:00 – 13:45, 20” interval



2: GNSSVLBI - simulation

Clock drift 1e-14 @ 50 min, 25 days simulated



2: GNSSVLBI - simulation

Simulated slant wet delay

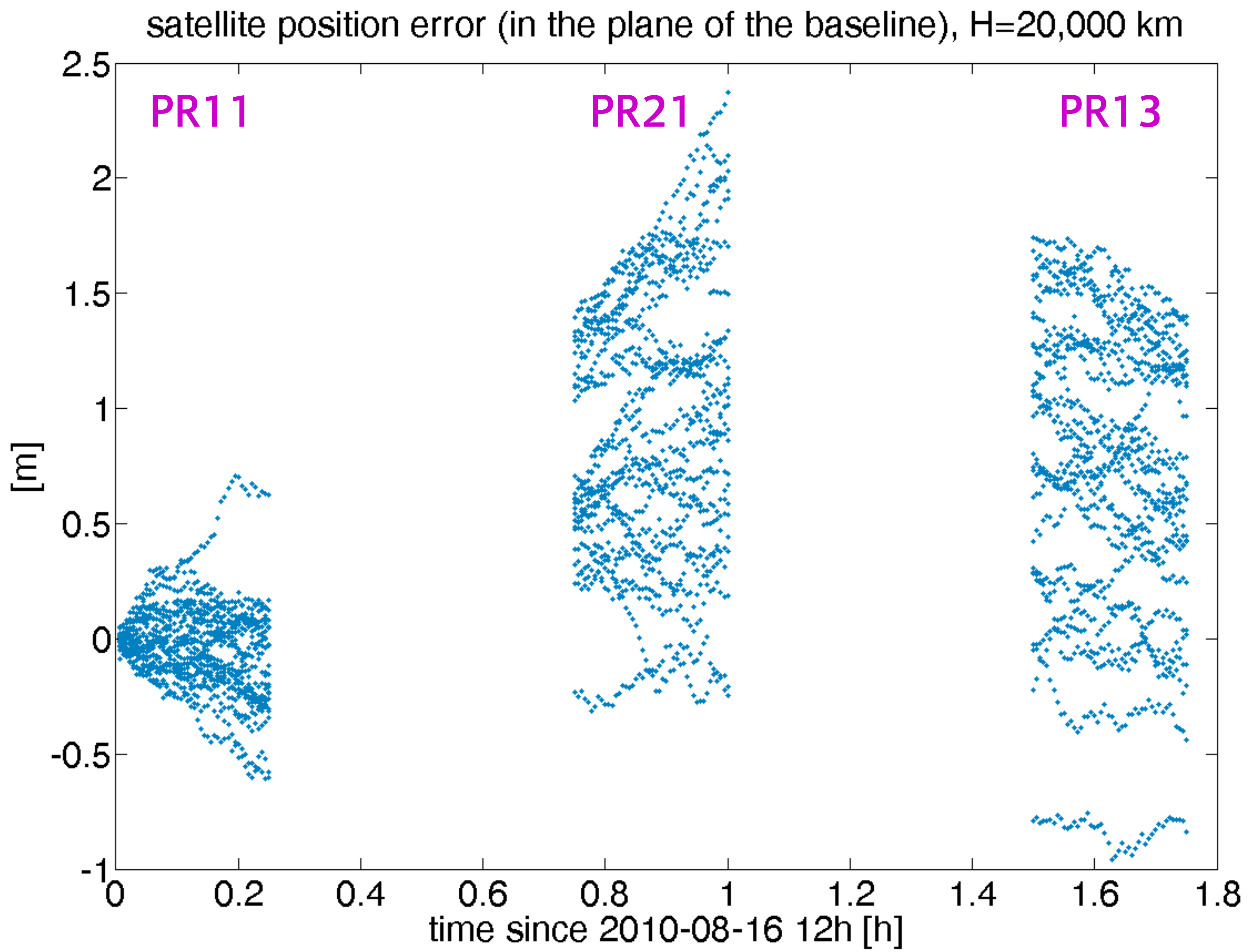
$C_n = 2.5^{-7} \ {}^{1}\!/_{m^3}$

$H = 2000\,m$

$wzd_0 = 150\,mm$

$v_n = 0\,{}^{m}\!/_{s}$

$v_e = 8\,{}^{m}\!/_{s}$



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Summary & outlook

- We successfully used VieVS to model delays of space VLBI applications; we implemented
  - Selene same beam data processing and
  - Glonass GNSS observations
- A simple estimation tool (vie_lsm_sc, vie_lsm_gnss) exists and can be used for simulations

TO DO:

- Improve model
  - External ionosphere / troposphere corrections
- Improve estimation part
  - Choose parameters
  - Constraints for trajectory of the space craft
- Continue work with real data

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THE END

Thank You for listening!

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References:

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).

Klioner, 1991: *General relativistic model of VLBI observables.* In: Carter WE (eds) Proceedings of AGU Chapman conference on geodetic VLBI: monitoring of global change. NOAA Technical Report NOS 137 NGS 49, AGU, Washington DC, pp 188-202.

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.

Tornatore et al., 2010: *Planning of an Experiment for VLBI Tracking of GNSS Satellites*, D. Behrend and K. D. Baver (eds), IVS2010 GM Proceedings, VLBI2010: From Vision to Reality.