# GNSS tracking by VLBI radio telescopes

L. Liu, J. Anderson, T. Nilsson, R. Heinkelmann, M. Xu, B. Soja,
Julian A. Mora-Diaz, V. Raposo-Polido, M. Karbon, C. Lu,
H. Schuh

liuli@gfz-potsdam.de

Helmholtz Centre Potsdam, GFZ German Research Centre for Geosciences

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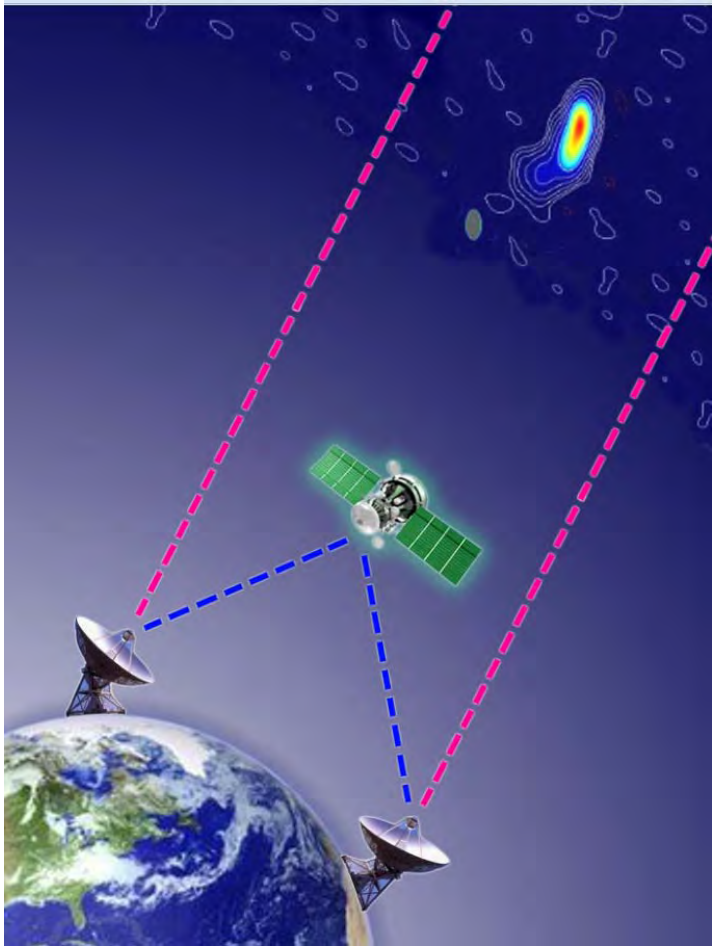
# Background of GNSS tracking by VLBI



## 1) Motivation

- Reference frame connection

  ICRF (kinematic) –-satellite orbit frame (dynamic)
- Space tie (vs. local tie)
- Detect systematic errors of the GNSS techniques
- Possible improvement of GNSS orbit

# Background of GNSS tracking by VLBI

## 2) Challenges

| | | | | | |
|---|---|---|---|---|---|
| 1 Technical | Quasar | S/X | 2.2~8.4GHz | Broadband | Slow |
| | GNSS | L | < 1.6GHZ | Narrowband | Fast |
| 2 Models | Quasar | Parallel light | | relativistic effects | |
| | GNSS | Spherical wave | | | |
| 3 Systematic errors | Quasar | Indepent EOP, clock break, offsets | | | |
| | GNSS | multi-path effects, receiver clock error | | | |

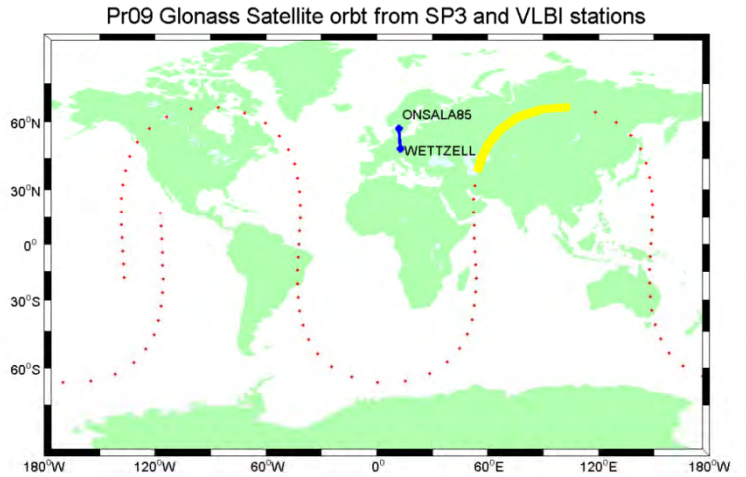
# Background of GNSS tracking by VLBI

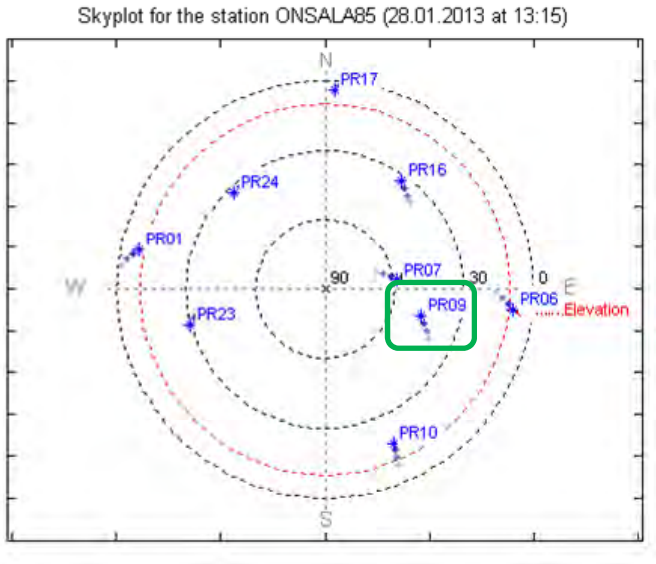
## 3) Recent Progress

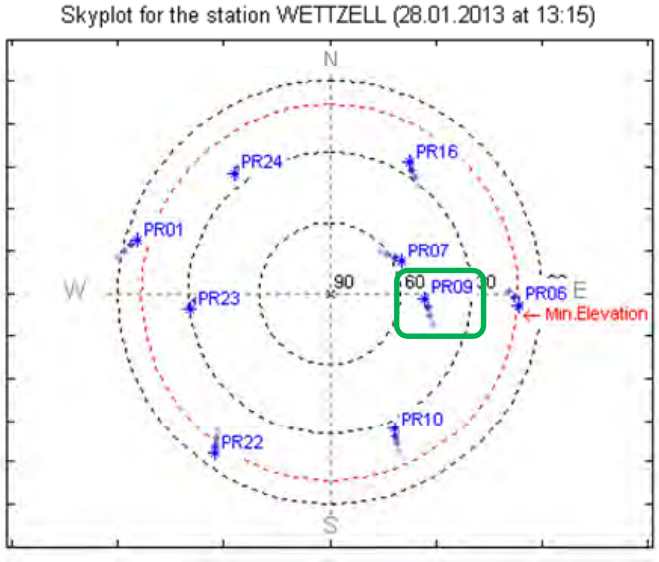
- Hase (1999) propose concept of the observations of GPS with VLBI to tie the GPS to ICRF
- Hase(1999) and Tornatore and Haas (2009) investigate the observability of GNSS signals with VLBI2010 system
- With SATTRACK module (Moya Espinosa and Haas 2007) can track satellite
- Tornatore(2010) demonstrate the technical realization with VLBI tracking of GLONASS satellites at L-band.
- Tornatore(2011) correlated the Onsala-Medicina single VLBI baseline GLONASS observations, and with an radio source 3c286 as a calibrator in Narrow-band and Board-band separately.
- Working group 1 of International VLBI service for Geodesy and Astrometry (IVS; Schuh and Behrend 2012) discussed the feasibility of using VLBI for GPS phase center mapping.
- Tornatore(2014) analysis the VLBI-GNSS observations, obtained 80ps delay residual in 1s for satellite
- With development of L- band receiver in Wettzell, the GLONASS satellite was observed by Wettzell-Onsala baseline for nearly an hour in Jan., 2013(Haas, 2014)

# A recent experiment

Pr09 Glonass satellite was successfully tracked by Wettzell and Onsala85 28.01.2013 at 13:15~13:59 (experiment: g130128, Pis: Neidhart, Haas, Haas,2014)

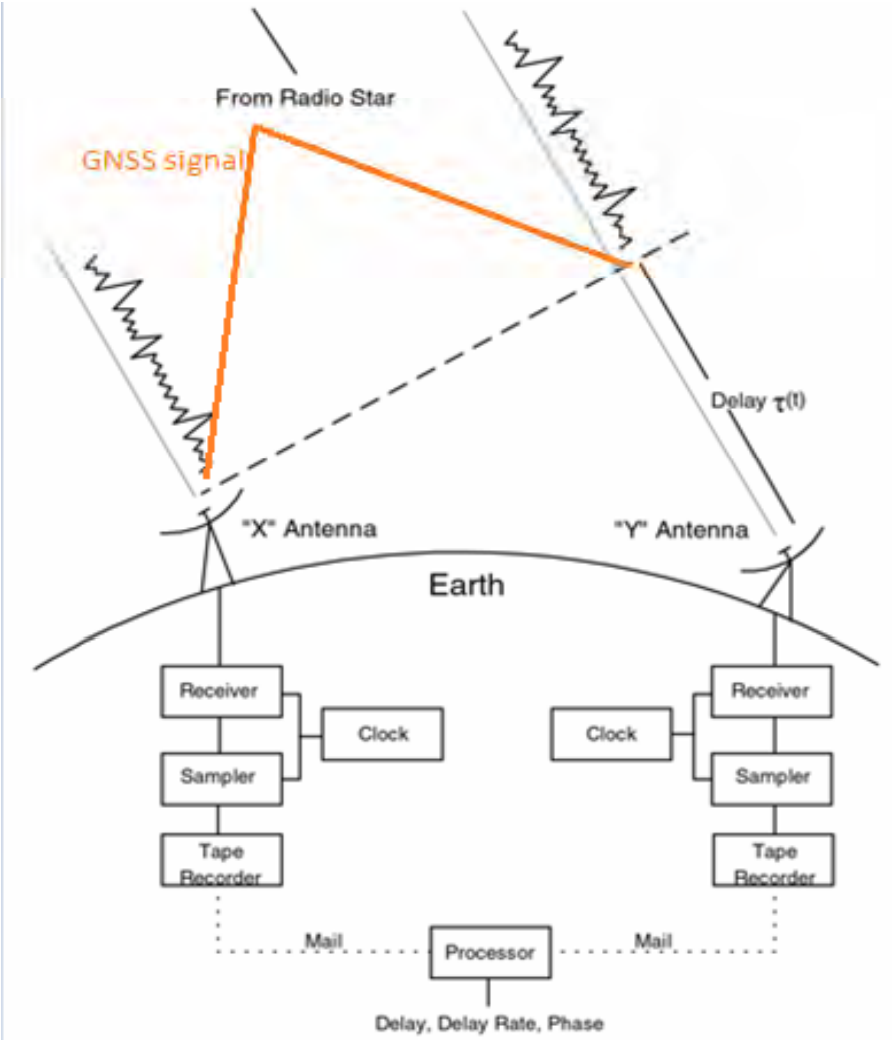


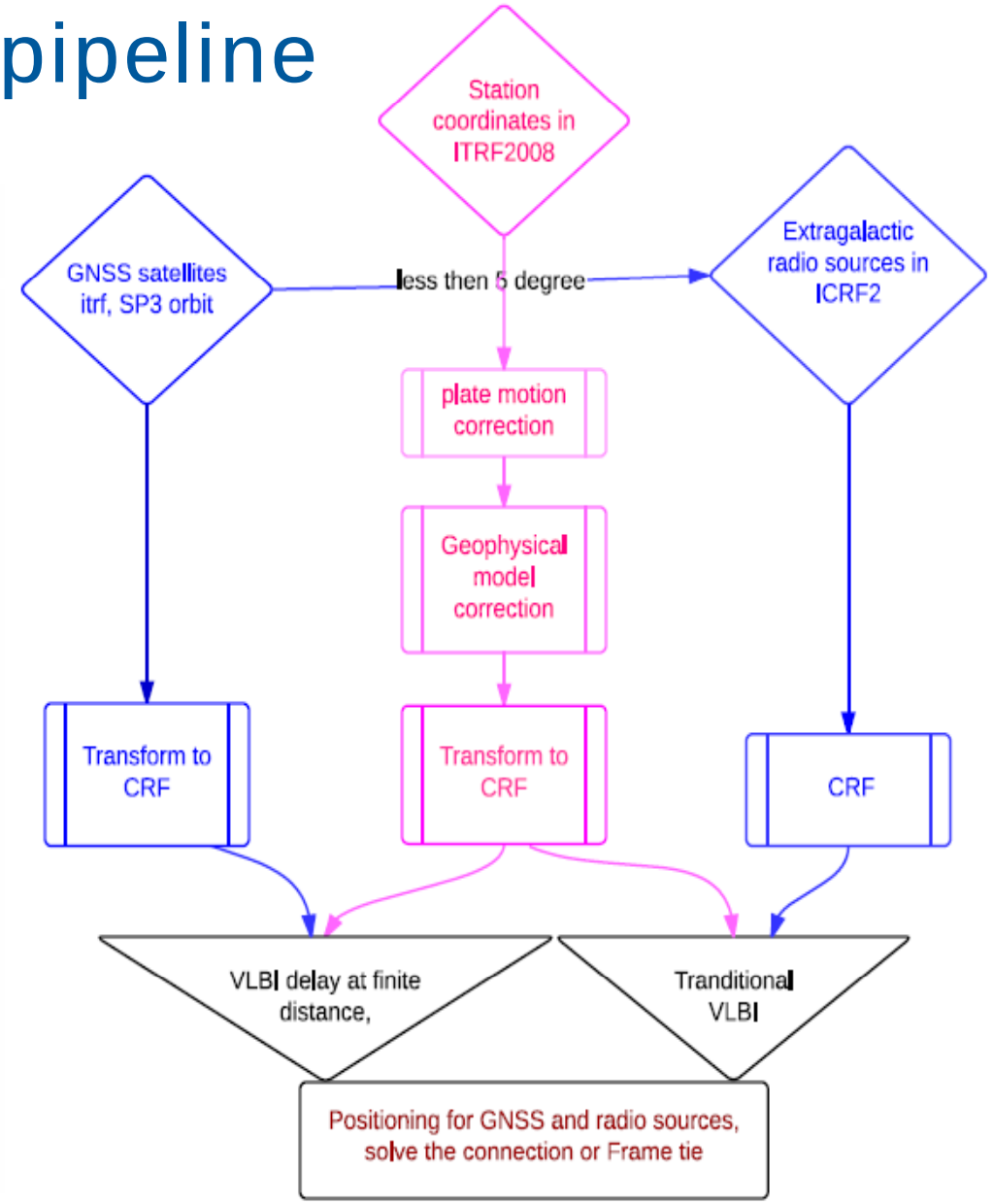




Estimated observation ability: Delay 1.3ns, phase 0.8d, rate 0.5mHz SNR30dB

# Data processing pipeline

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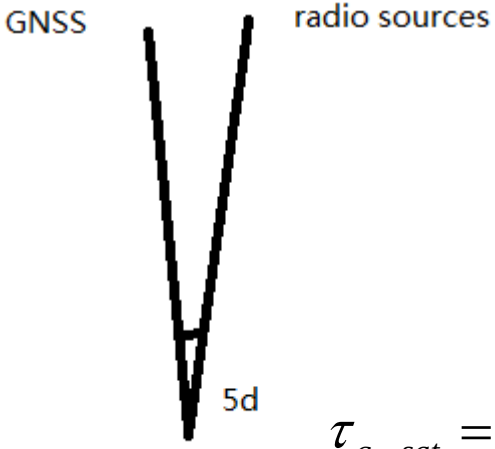
# Simulation based on the real observation

- Simulation strategy—(General ideal: *use real observations*)
  - Switch observations between GNSS and VLBI with angular distance less then 5 degree
  - VLBI observation generated by Cont 14 observations
  - GNSS observation from the co-located GNSS observations
  - Time delay observations: clean GNSS delay, and VLBI group delays

- Estimation
  - IERS Conventions 2010 for radio sources
  - Sekido (2006) Time delay at finite distance for GNSS
  - Moyer (2000) Gravitational delay for earth satellite

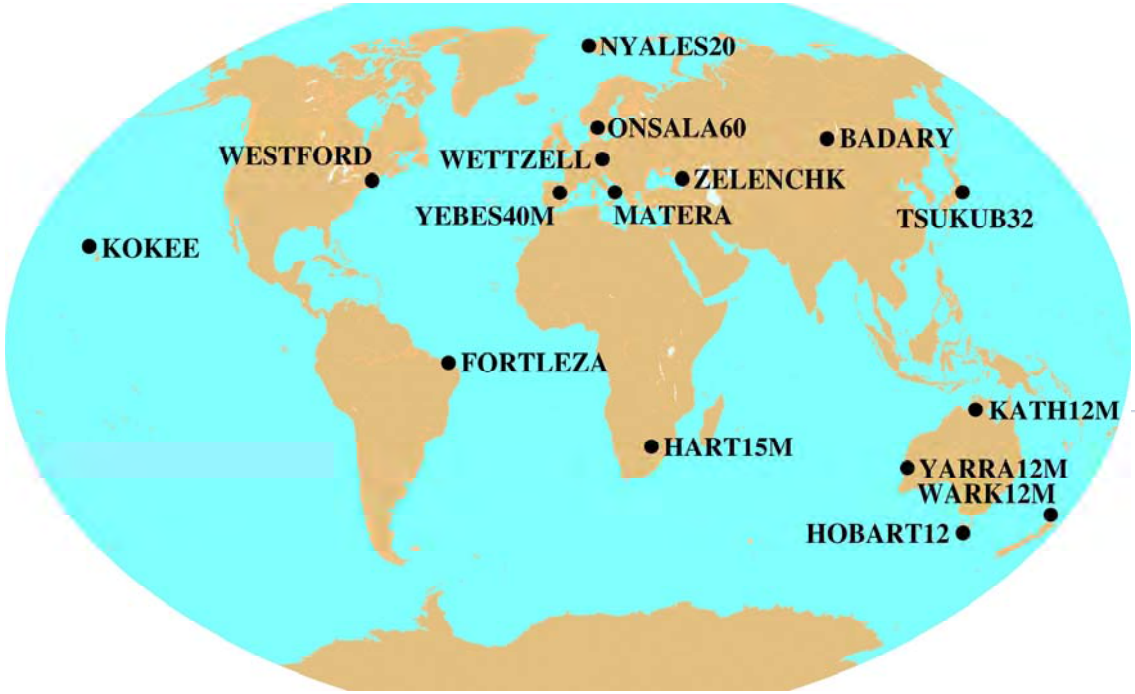



$$\tau_{err\_ers} \approx \tau_{err\_sat}$$

$$\tau_{g\_sat} = \tau_{o\_sat} - \left(\tau_{o\_ers} - \tau_{g\_ers}\right)$$

# Simulation based on the real observation

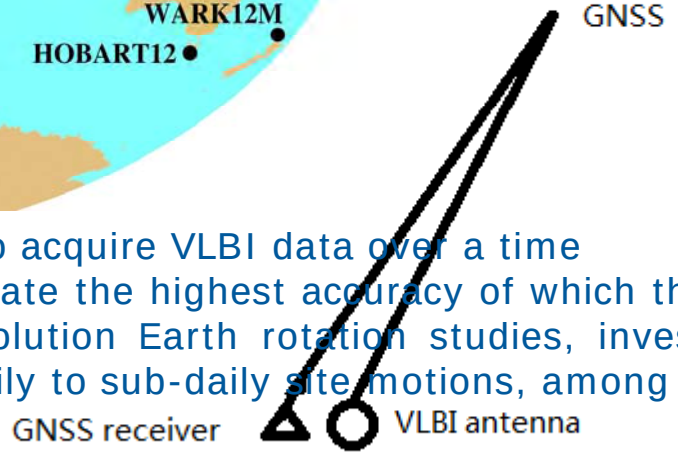
*17 VLBI stations in Cont14*




*GNSS co-located stations*

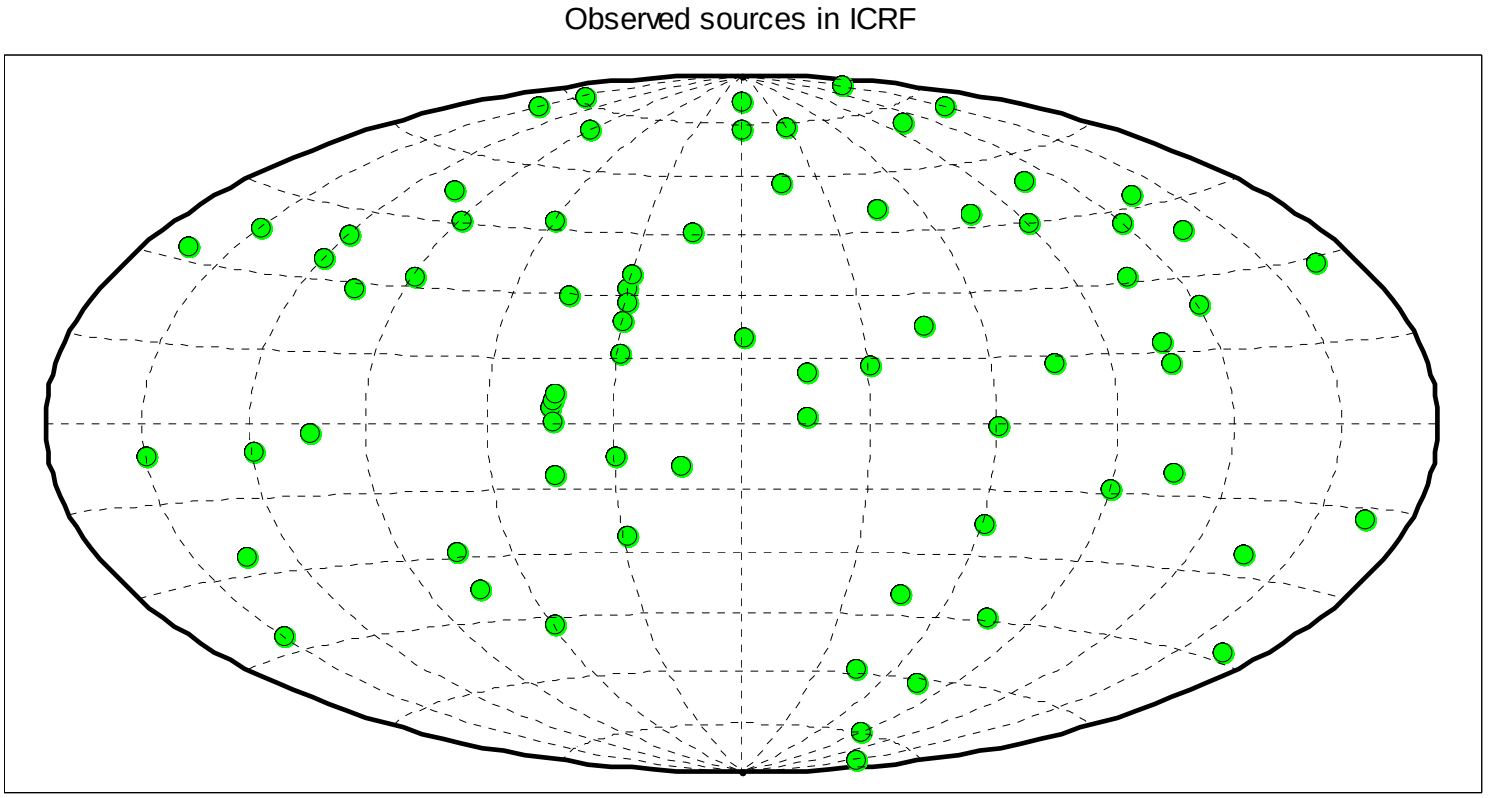
nya1
wes2
onsa
zeck
badg
tskb
kokb
wtzr
yebe
brft
harb
wark
hob2
yarr
mate
Kat1

The plan for the CONT14 campaign is to acquire VLBI data over a time period of about two weeks to demonstrate the highest accuracy of which the current VLBI system is capable. This will support high resolution Earth rotation studies, investigations of reference frame stability, and investigations of daily to sub-daily site motions, among other things



# Simulation based on the real observation

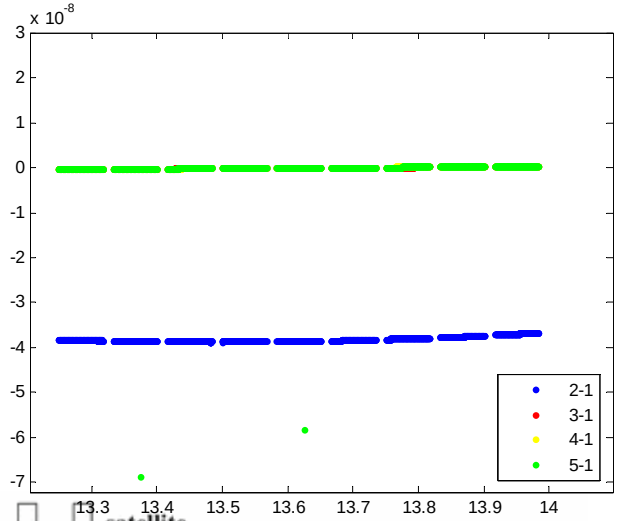
## *Radio sources observed in session **14MAY08XA***

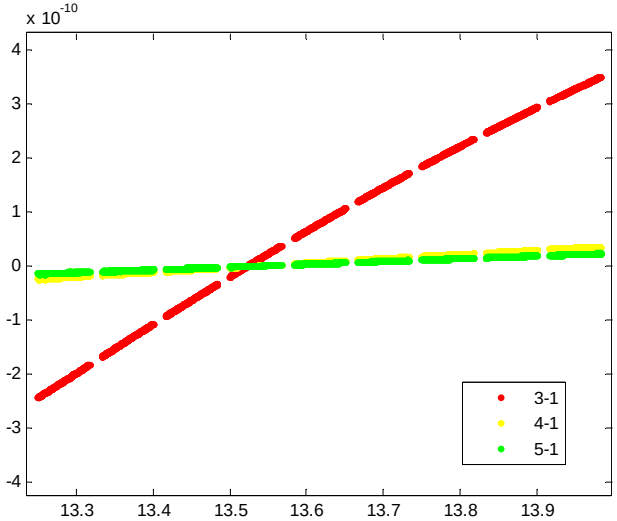


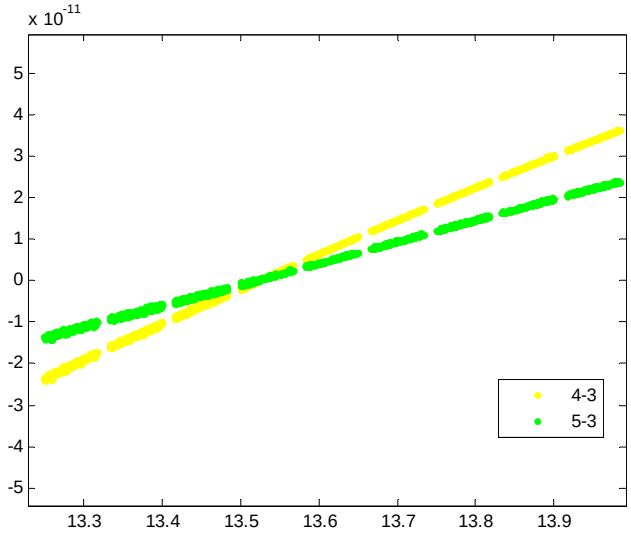

73 radio sources observed

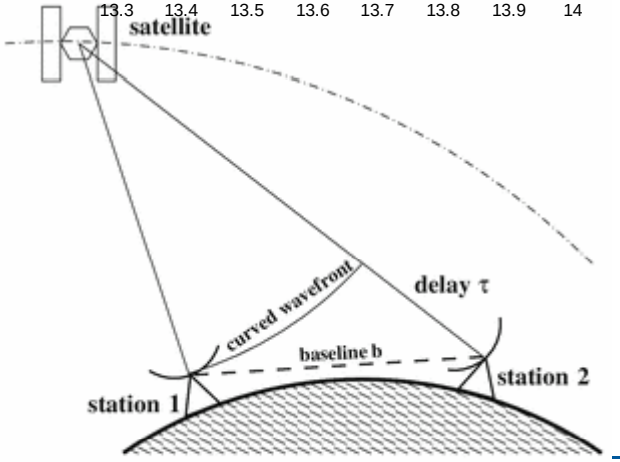
# Analysis & Results

## *Comparison between different delay models for GNSS*




(Tornator, 2014)

1 Sekido 2006 (BCRS, finite)
2 Duev 2012 (geocenter correction) used in correlation
3 Fukushima 1994 (iteration)
4 Consensus 2010 (pseudo source)
5 Klioner 1992 (length difference)

# Analysis & Results

Problems may occur

- Both GNSS stations may not observe the same satellite

– Locate the satellites which could be observed by two stations, we can analysis the systematic errors in two systems and compare them with

1) different angular distance

2) different baseline lengths

- The common-visual GNSS satellite is not close to the radio sources in the near epoch

– Choose the satellite with relatively small angular distance with radio sources

1)DVLBI

# Summary

- Test study for recent VLBI-GNSS observation, observation ability was estimated
- Simulation observation with real observation from Cont14 VLBI observation and co-located GNSS observation
- Compare different delay models for GNSS observation
- Analyze the possible problem in this strategy

# Outlook

- Test the simulation results, compare the residuals from two system
- Relativistic effects on orbit determination
- Analyze the systematic errors in GNSS systems

# Thanks for your attention!

liuli@gfz-potsdam.de

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