# VLBI simulations to GRASP-like satellites at GFZ

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**First International Workshop on VLBI Observations of Near-field Targets**

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# Outline

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## Co-location in space

- Scientific goal: Meeting the requirements on a global TRF with an accuracy of 1 mm and a stability of 0.1 mm/yr

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## GFZ contribution

- VLBI simulations to (E-)GRASP

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- 10 stations: typical 10 station IVS global network
- 20 stations: 10 station network plus VLBA (Astronomy, U.S.)
- 30 stations: 20 station network plus extra 10 European stations

# Station networks

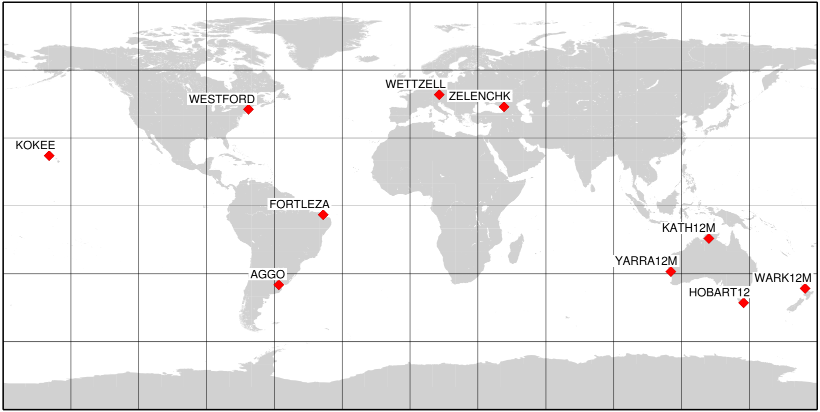


Figure: 10 stations network (IVS stations)

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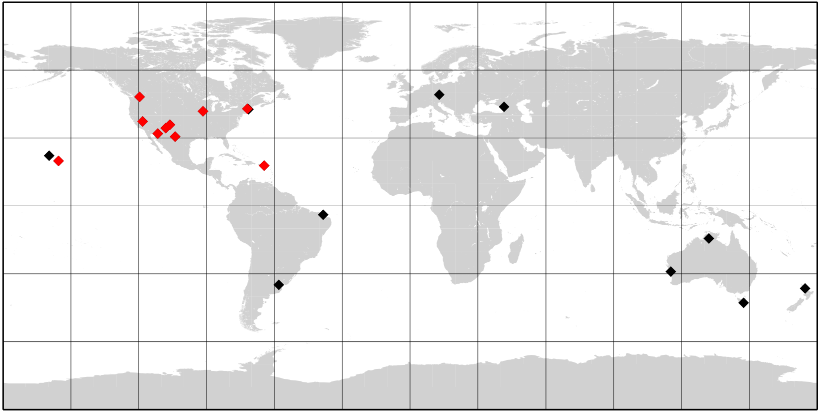

Figure: 20 stations network (IVS + VLBA stations)

# Station networks

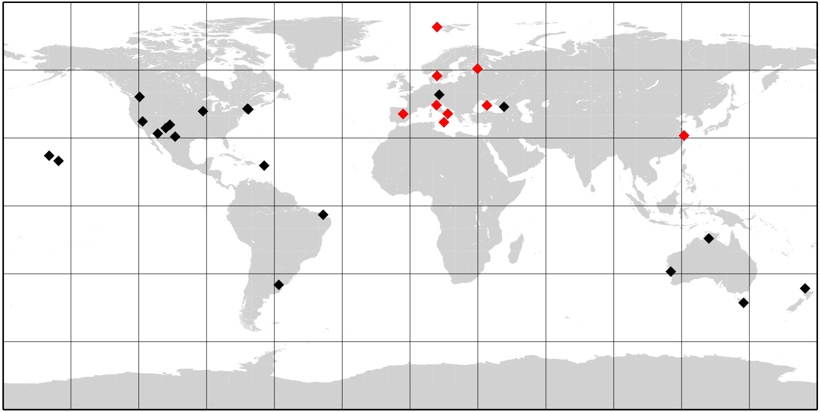

Figure: 30 stations network (IVS+VLBA+additional European stations)

# VieVS@GFZ Simulations

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## 1. Scheduling

- For each network, a standard 24 h VLBI schedule (observing quasars) was generated with VIE_SCHED (Sun et al., 2014)
- Satellite observations added when possible
  - A station observes the satellite whenever it and at least one other station can track it above 10° elevation angle
  - 2 minutes sampling interval
  - Quasar observations from ±2 minutes relative to the satellite observation removed

# VieVS@GFZ Simulations

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- VLBI observations simulated for the schedules with VIE_SIM
- Simulation of the random error sources:
  - Zenith wet delays based on the turbulence model of Nilsson and Haas (2010)
  - Station clocks modeled as random walk plus integrated random walk processes (Herring et al., 1990) with an Allan standard deviation $ASD = 1 \cdot 10^{-14}$@50 min
  - White noise of 30 ps

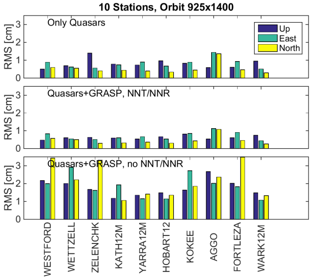
# VieVS@GFZ Simulations

## 3. Estimation

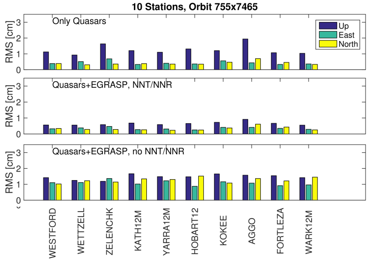
- Simulated observations analyzed with the VieVS2tie software (Plank et al., 2014)
  - Estimated parameters: clocks, ZWD, gradients, EOP, station coordinates
  - Quasar coordinates and (E-)GRASP orbit fixed
  - 3 solutions:
    - a) Original quasar only schedule
    - b) Quasar + (E-)GRASP schedule, applying NNT/NNR for datum definition
    - c) Quasar + (E-)GRASP schedule, no datum constraints (datum realized by the known (E-)GRASP orbit)

# 10 Stations (RMS Scatter)

## 925x1400 Orbit




## 755x7465 Orbit



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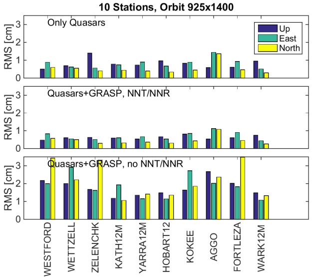


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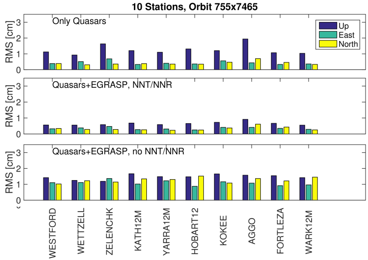
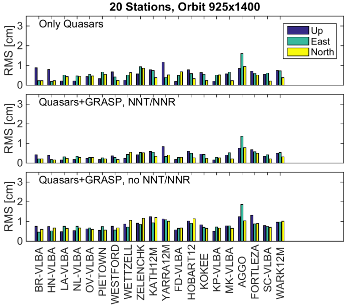



- Improvement when (E-)GRASP observations are used in addition to quasar ones, relative to quasar only.
- Without NNT/NNR, repeatabilities get worse. Smaller degradation for E-GRASP.

# 20 Stations (RMS Scatter)

## 925x1400 Orbit

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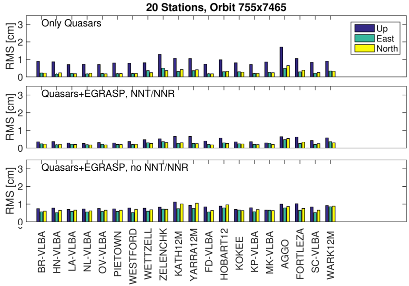
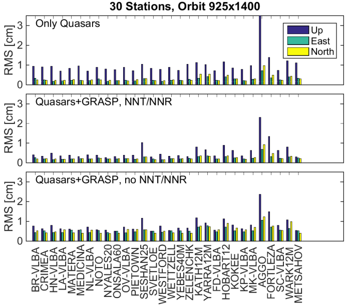



- Sub-centimeter accuracy for 13 (GRASP) and 17 (E-GRASP) out of the 20 stations and the known orbit.

# 30 Stations (RMS Scatter)

## 925x1400 Orbit

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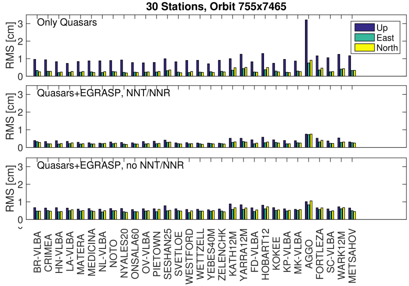
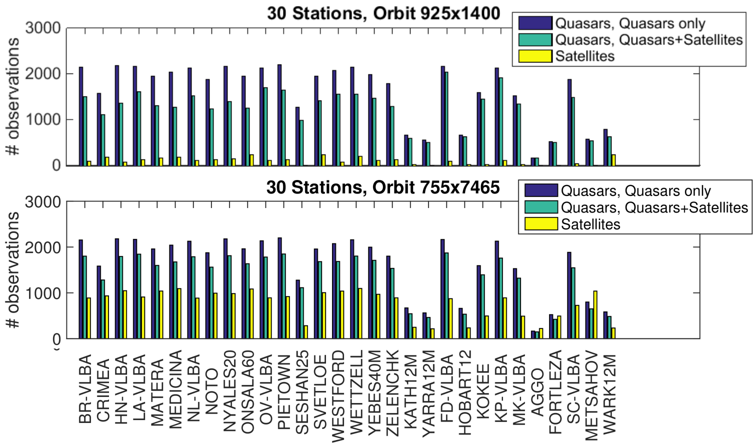


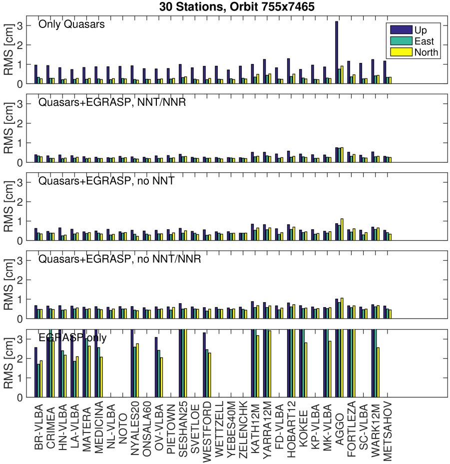

- Sub-centimeter accuracy for 24 (GRASP) and 29 (E-GRASP) out of the 30 stations and the known orbit.

# 30 Station network: Number of observations




- More observations to E-GRASP possible.

# 30 Stations and 755x7465 Orbit (RMS Scatter)




- Insufficient estimation in case of only VLBI observations to E-GRASP.

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## Simulations of the VLBI Accuracy of E-GRASP

- Simplistic simulations outside of VieVS@GFZ including measuring the spacecraft position/velocity were developed based on **error analysis** techniques.

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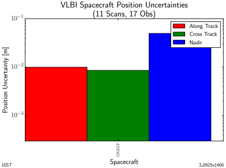
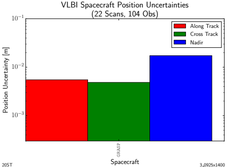
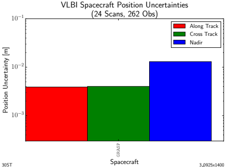
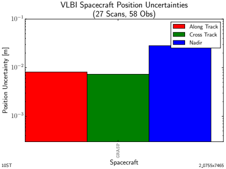
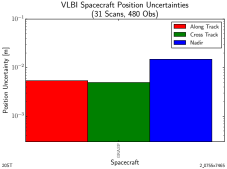
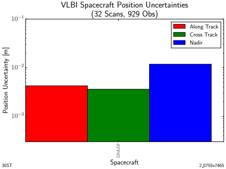
- Simplistic simulations outside of VieVS@GFZ including measuring the spacecraft position/velocity were developed based on **error analysis** techniques.
- Reasonable estimates of uncertainties in quantities related to the measurement process are used, including uncertainties in
    - delay measurements
    - rate measurements
    - atmosphere
    - station position displacements
    - spacecraft position and velocity offsets
    - spacecraft orientation
    - clock offsets and clock rate offsets

# Spacecraft Position Uncertainty: 2 Orbits x 3 Networks

| Orbits/ #Stations | 10 | 20 | 30 |
| --- | --- | --- | --- |
| 925x1400 |  |  |  |
| 755x7465 |  |  |  |









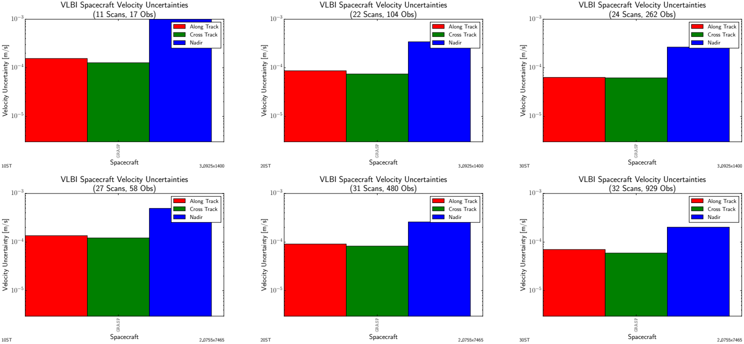




- Improvement in case of more stations and more dense networks (VLBA, Europe).
- Along and cross track direction position uncertainties of about 5 mm, in nadir of about 1 cm.

# Spacecraft Velocity Uncertainty: 2 Orbits x 3 Networks

| Orbits/ #Stations | 10 | 20 | 30 |
| --- | --- | --- | --- |
| 925x1400 | | | |
| 755x7465 | | | |




- Improvement in case of more stations and more dense networks (VLBA, Europe).
- Spacecraft velocity uncertainty better than $1\,\frac{\mathrm{mm}}{\mathrm{s}}$.

# Station Position Uncertainty: 2 Orbits x 3 Networks

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|---|---|---|---|
| 925x1400 | | | |
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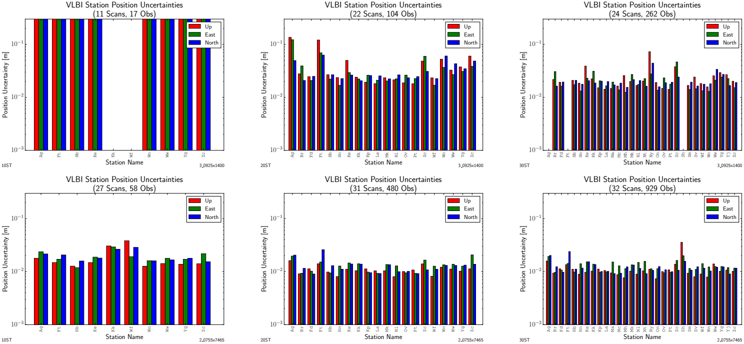


- Station position uncertainty of about 1 cm.

# Spacecraft tracking rates

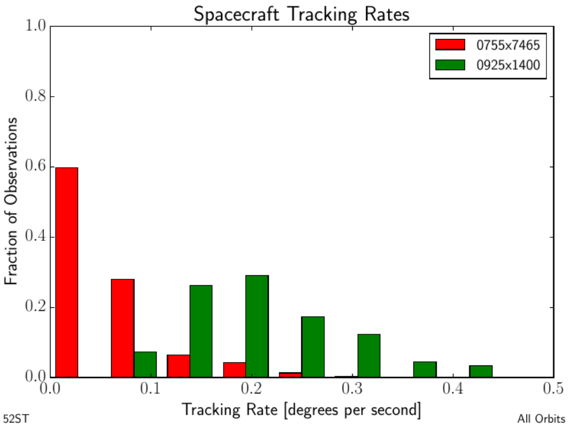


Figure: Fraction of VLBI observations as a function of spacecraft tracking rate

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Thank you very much for your attention.

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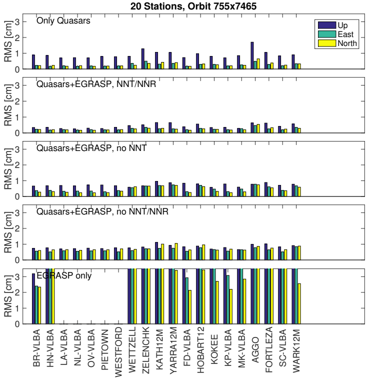
# 755x7465 Orbit (RMS Scatter)

## 20 Stations




## 30 Stations