# GIOVE-A PRECISE ORBIT DETERMINATION FROM MICROWAVE AND SATELLITE LASER RANGING DATA - FIRST PERSPECTIVES FOR THE GALILEO CONSTELLATION AND ITS SCIENTIFIC USE

E. Schönemann [1], T. A. Springer [2], M. Otten [2], M. Becker [1], J. Dow [2]

(1) Institut für Physikalische Geodäsie, Technische Universität Darmstadt

(2) Navigation Support Office, European Space Operations Center

TECHNISCHE UNIVERSITÄT DARMSTADT

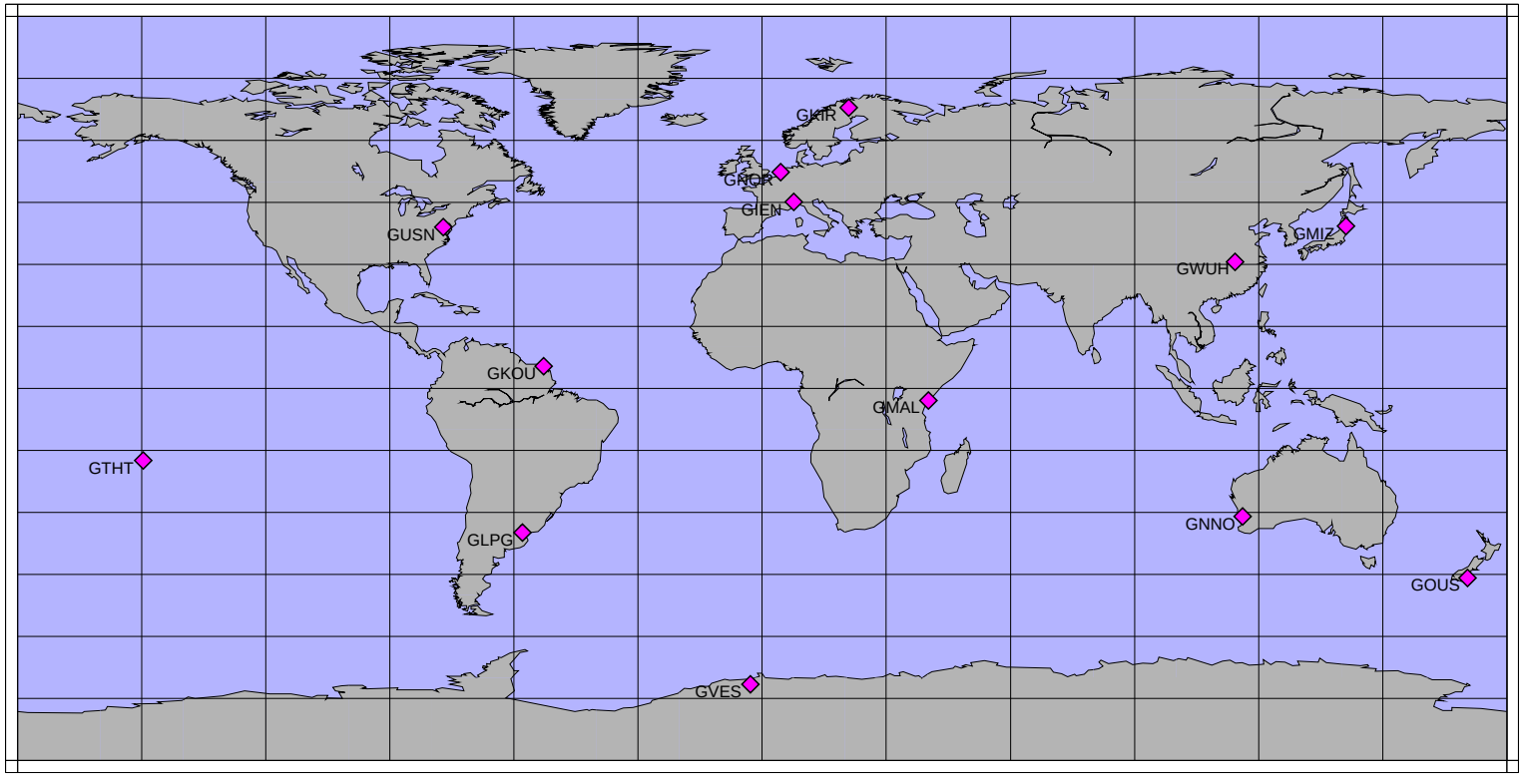
# Motivation for this analysis

The navigation office of the ESOC is engaged in various activities using the GIOVE-A observations, recorded at the GESS.

The overall goal is the scientific use of the future GALILEO constellation within the tasks and goals of ESA and the IGS.

Key elements of the future applications are proper modelling of GALILEO orbits and assessment of quality and performance of the observables.

# GESS tracking network



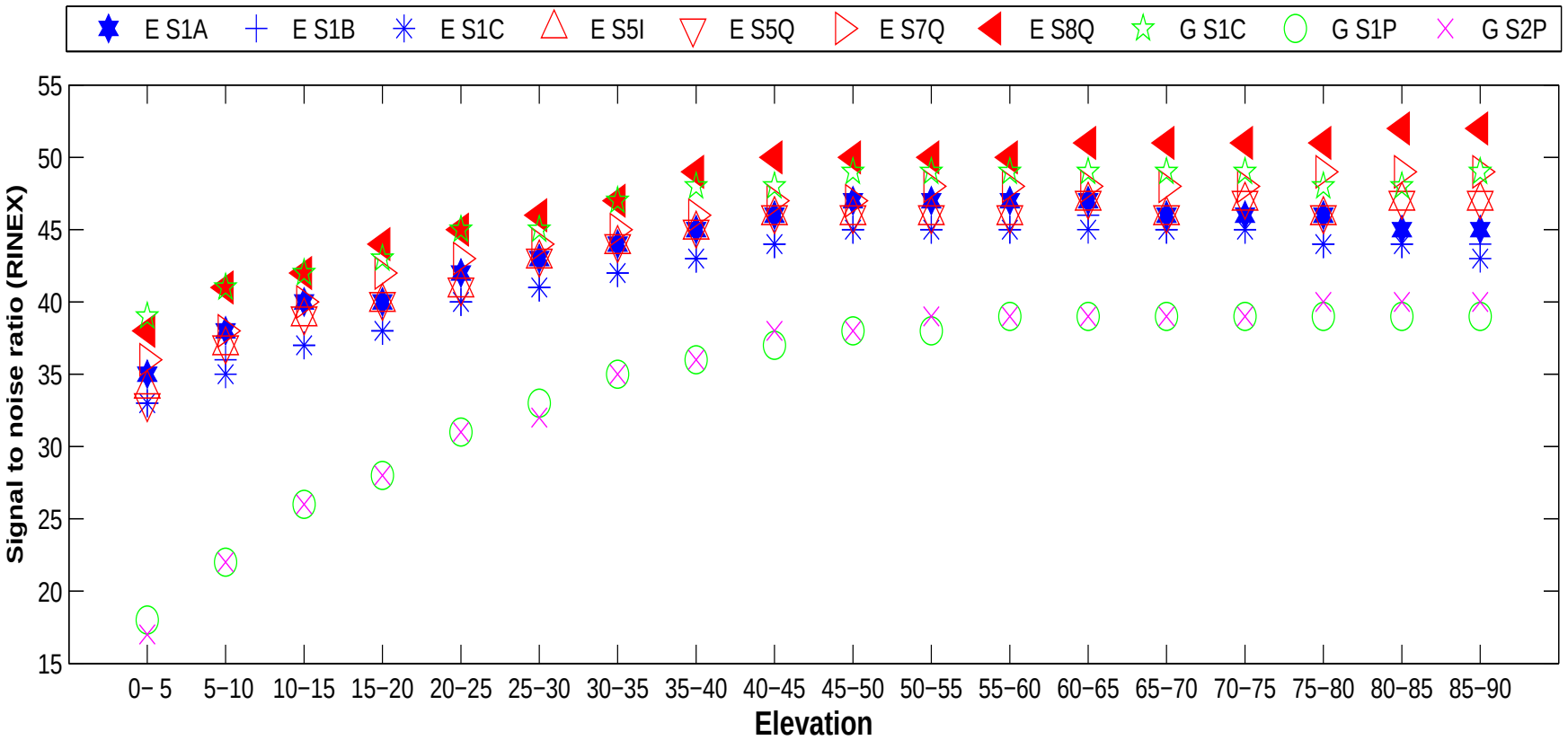

Analysed time span $16^{th}$ - $27^{th}$ December 2006

TECHNISCHE UNIVERSITÄT DARMSTADT

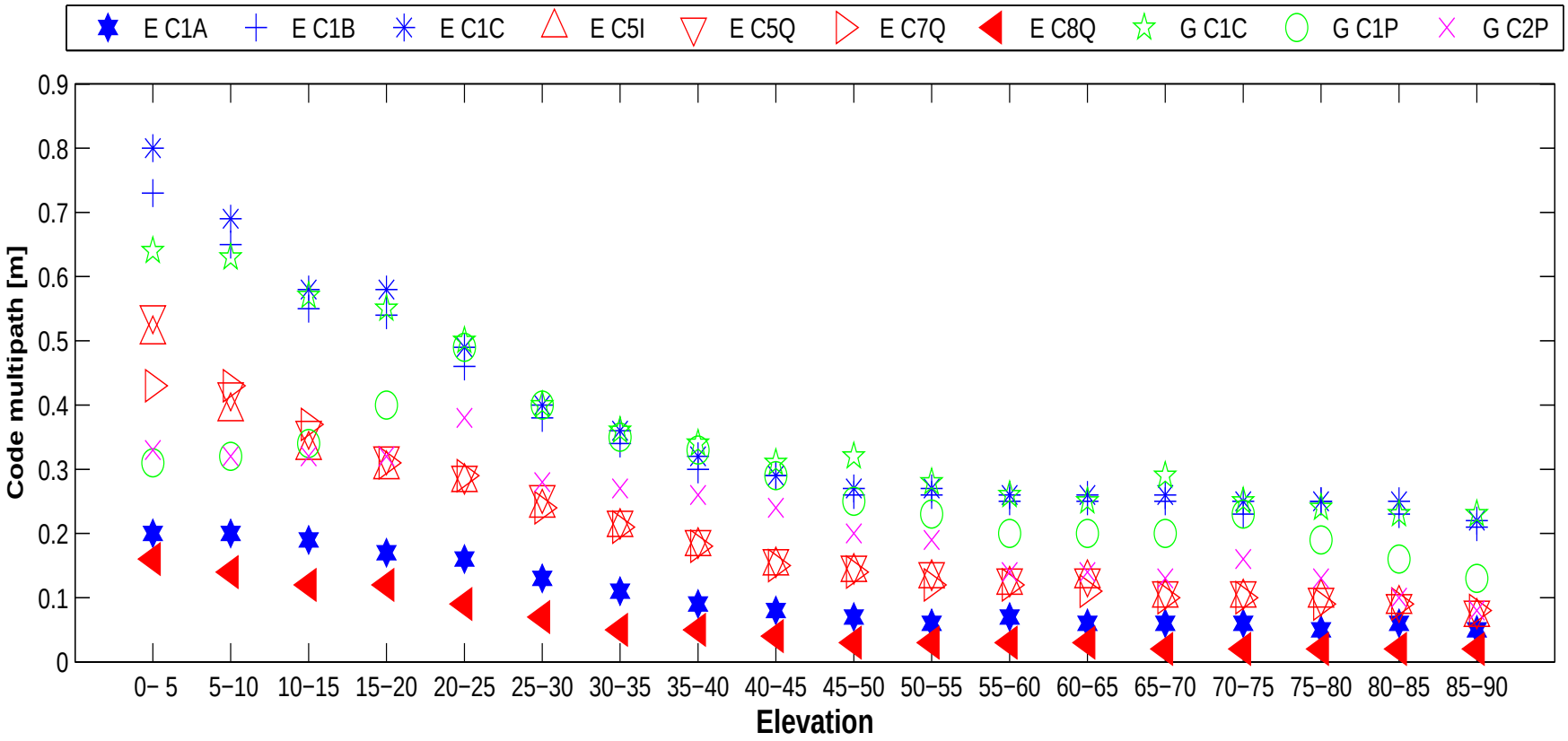
# Analysed signals

| Signal | Components | RINEX Name | Modulation Type | Carrier | RINEX Name |
|---|---|---|---|---|---|
| G1 | C/A data | C1C | BPSK(1) | 1575.42MHz | L1C |
| | P data | C1P | BPSK | | L1P |
| E1 | E1-A | C1A | BOC(15,2.5) | 1575.42MHz | L1A |
| | E1-B data | C1B | BOC(1,1) | | L1B |
| | E1-C pilot | C1C | | | L1C |
| G2 | P data | C2P | BPSK | 1227.60MHz | L2P |
| E5 | E5a-I data | C5I | BPSK(10) | 1176.45MHz | L5I |
| | E5a-Q pilot | C5Q | | | L5Q |
| | E5b-Q pilot | C7Q | | 1207.14MHz | L7Q |
| | E5a+E5b | C8Q | AltBOC(15,10) | 1191.795MHz | L8Q |

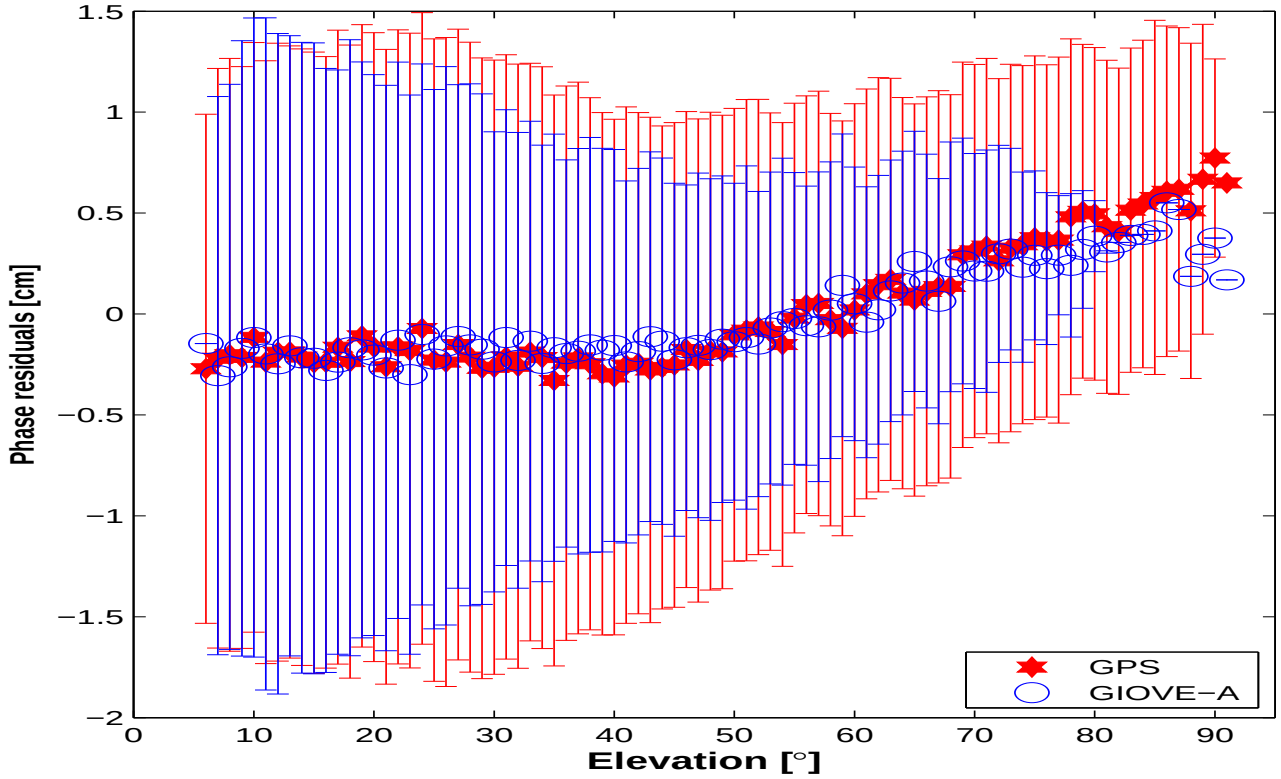
# Signal to noise ratio (SNR)



# Code multipath vs. elevation



# Ionosphere free precise point positioning phase residuals




13 GESS over 154 days were analysed
from 12$^{th}$ September 2006 until 26$^{th}$ May 2007

# Conclusion I

- GPS C1C and GIOVE C1B/C1C (open signals) show comparable multipath behaviour
- GPS C1P/C2P (precise) and GIOVE-A C5I/C5Q/C7Q show a comparable multipath behaviour
- GIOVE-A C1A (PRS) and C8Q (combined) have the best multipath

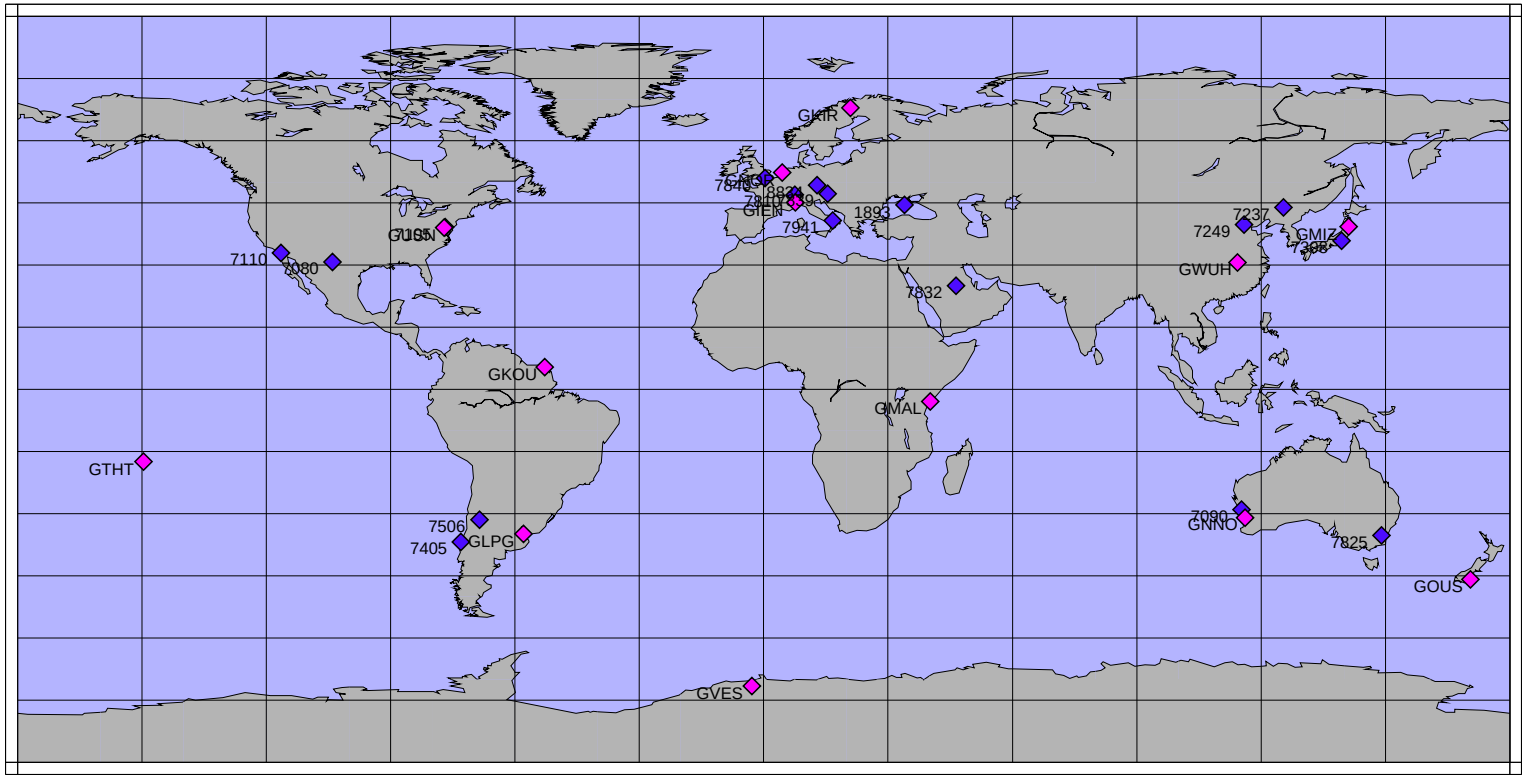
# Part 2. Orbit quality

- Internal orbit consitency
- Validation of the orbits
- Comparison of the microwave and SLR orbits (best arc length)
- Solar radiation pressure parameters

# Analysed orbits

- SLR only solution (arc length 7day)
- Microwave only (GNSS only solution, arc length 1-5 days)
- Microwave and SLR (GNSS and SLR combined solution, arc length 1-5 days)

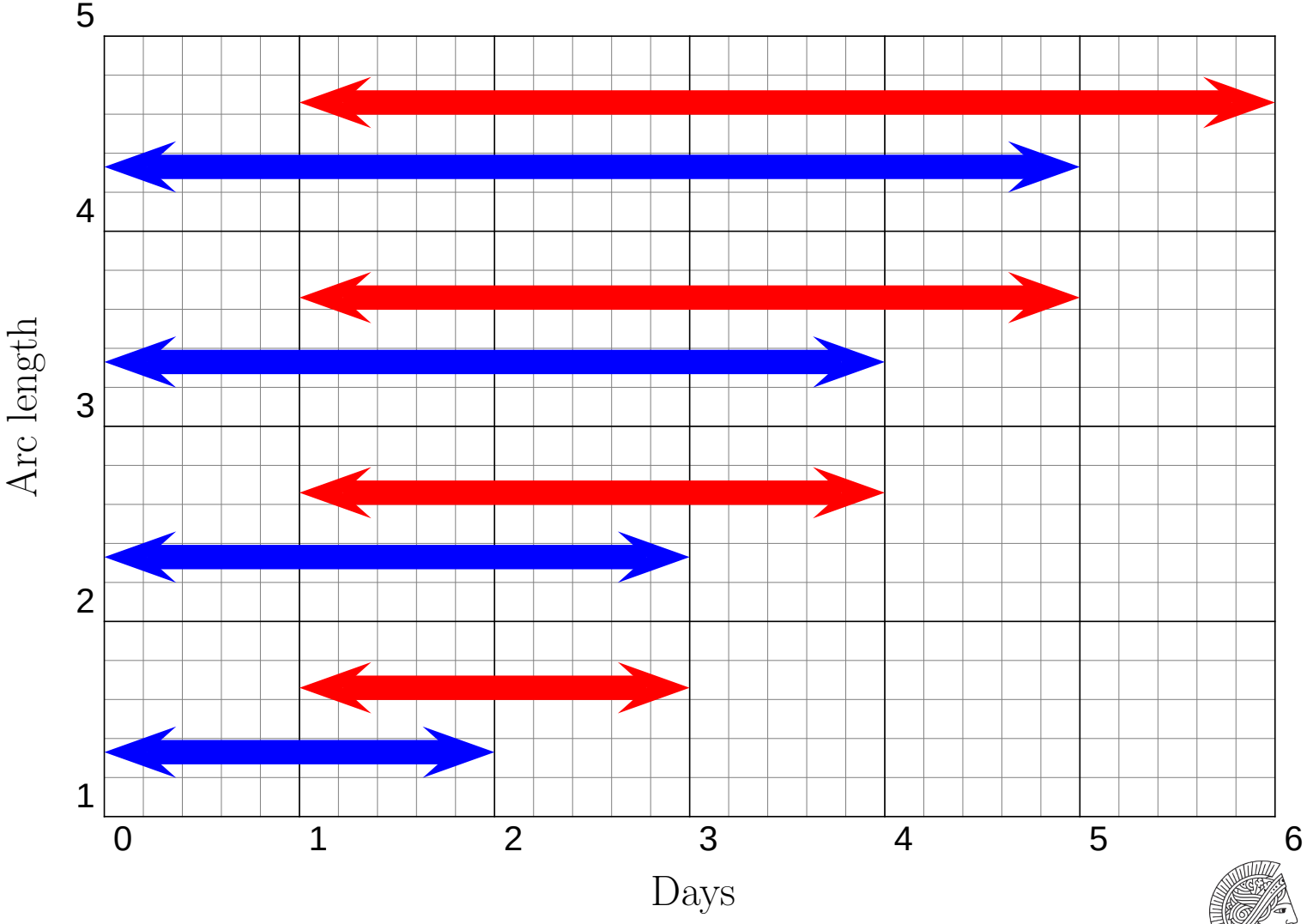
# Tracking network GESS + SLR



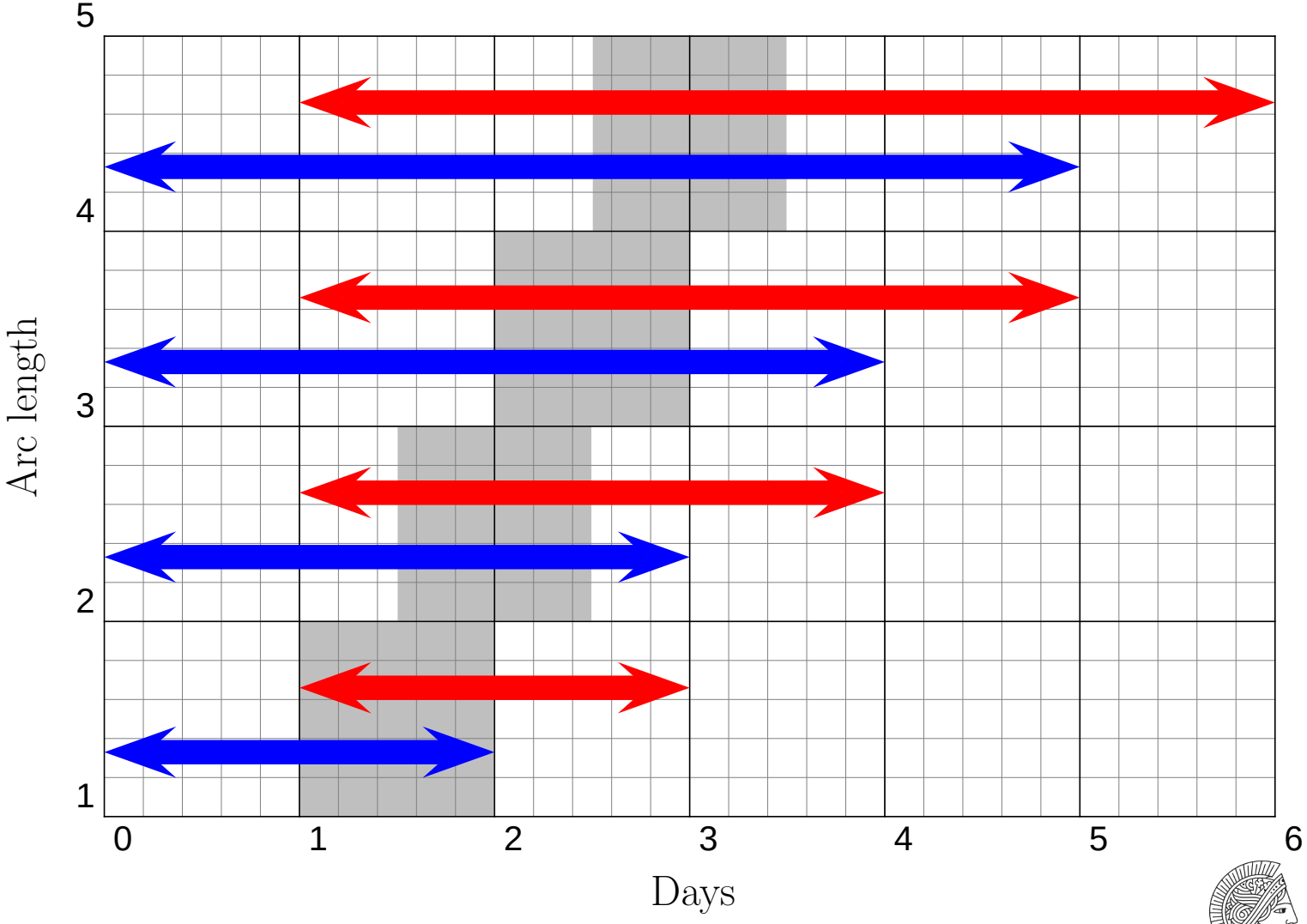

13 GESS and 12 SLR stations over 154 days were analysed from $12^{th}$ September 2006 until $26^{th}$ May 2007

TECHNISCHE UNIVERSITÄT DARMSTADT

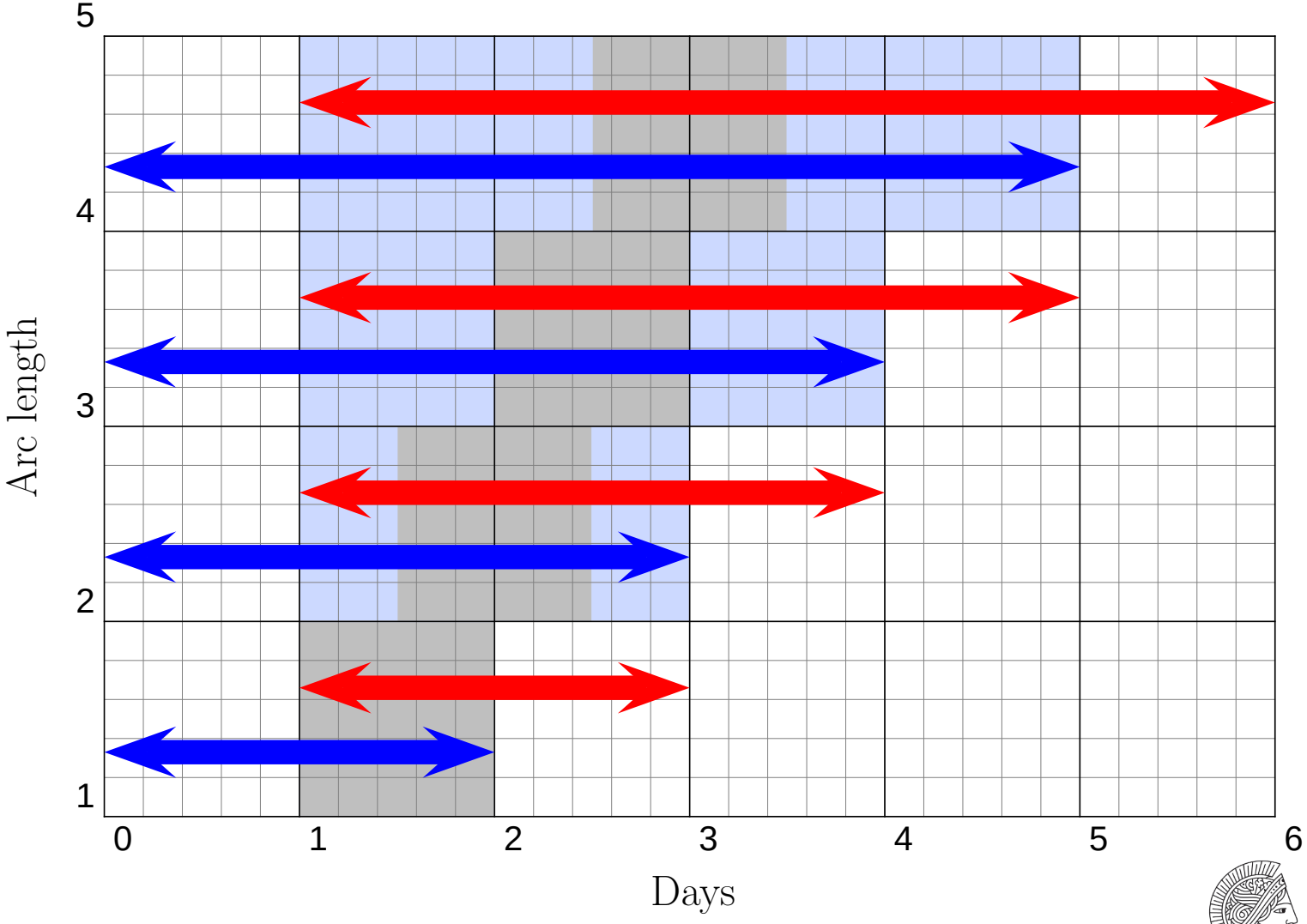
# Testing of the internal orbit consistency



# Testing of the internal orbit consistency



# Testing of the internal orbit consistency



# Internal orbit consistency of different arc length

| | Microwave only | | | | | Microwave and SLR | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1d | 2d | 3d | 4d | 5d | 1d | 2d | 3d | 4d | 5d |
| Part 1 | 662 | 254 | 146 | 131 | 127 | 505 | 172 | 110 | 81 | 84 |
| Part 2 | 221 | 99 | 52 | 41 | 42 | 185 | 80 | 41 | 34 | 31 |

RMS [mm] of the GIOVE-A orbit

# Internal orbit consistency of different arc length

| | Microwave only | | | | | Microwave and SLR | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1d | 2d | 3d | 4d | 5d | 1d | 2d | 3d | 4d | 5d |
| Part 1 | 662 | 254 | 146 | 131 | 127 | 505 | 172 | 110 | 81 | 84 |
| Part 2 | 221 | 99 | 52 | 41 | 42 | 185 | 80 | 41 | 34 | 31 |

RMS [mm] of the GIOVE-A orbit

| | Microwave only | | | | |
|---|---|---|---|---|---|
| | 1d | 2d | 3d | 4d | 5d |
| Part 1 | 90 | 57 | 29 | 35 | 55 |
| Part 2 | 67 | 27 | 15 | 12 | 12 |

RMS [mm] of the GPS-35 satellite treated in the same way as GIOVE-A test satellite

# Orbit validation against SLR, using different orbit solutions

| | SLR | Microwave only | | | | | Microwave and SLR | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 7d | 1d | 2d | 3d | 4d | 5d | 1d | 2d | 3d | 4d | 5d |
| Part 1 | 54 | 1046 | 448 | 280 | 316 | 333 | 91 | 120 | 124 | 168 | 167 |
| Part 2 | 76 | 375 | 228 | 200 | 214 | 214 | 98 | 121 | 136 | 160 | 168 |

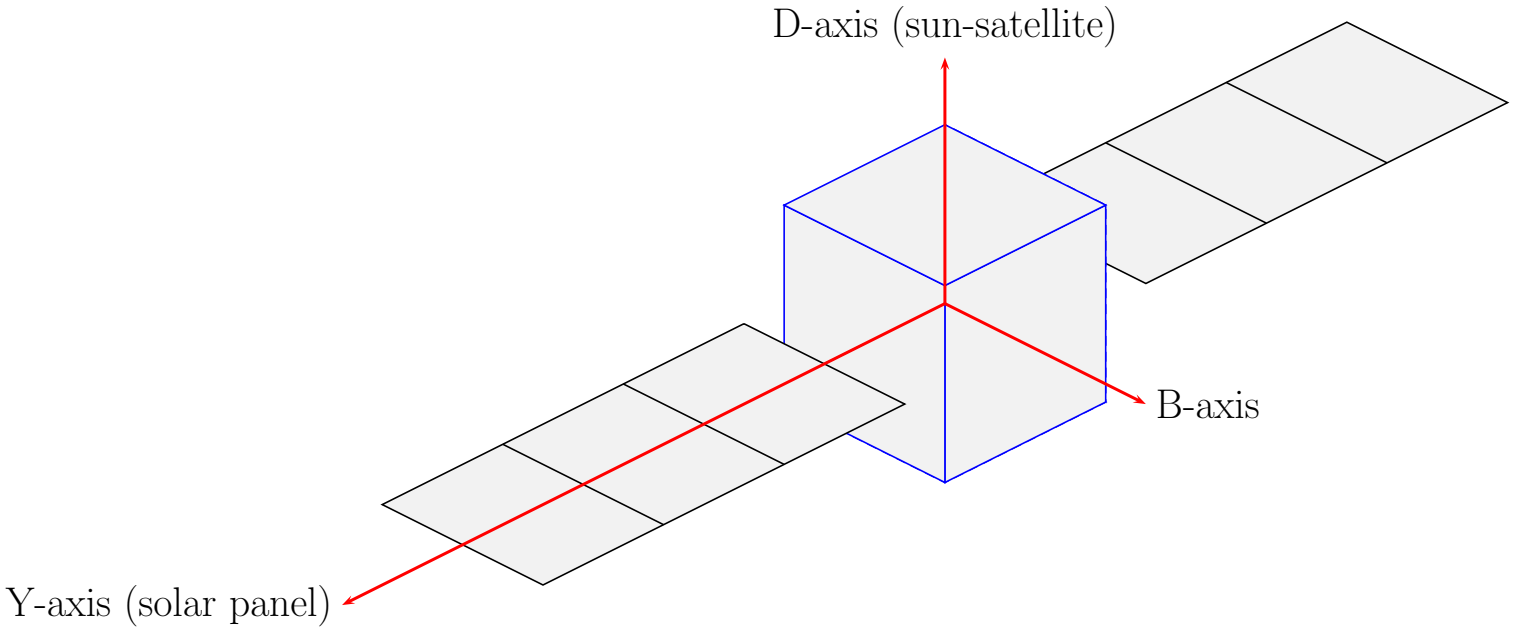
RMS of the 2-Way-SLR residuals [mm]

# Orbit comparison, of the best solution (3 day)

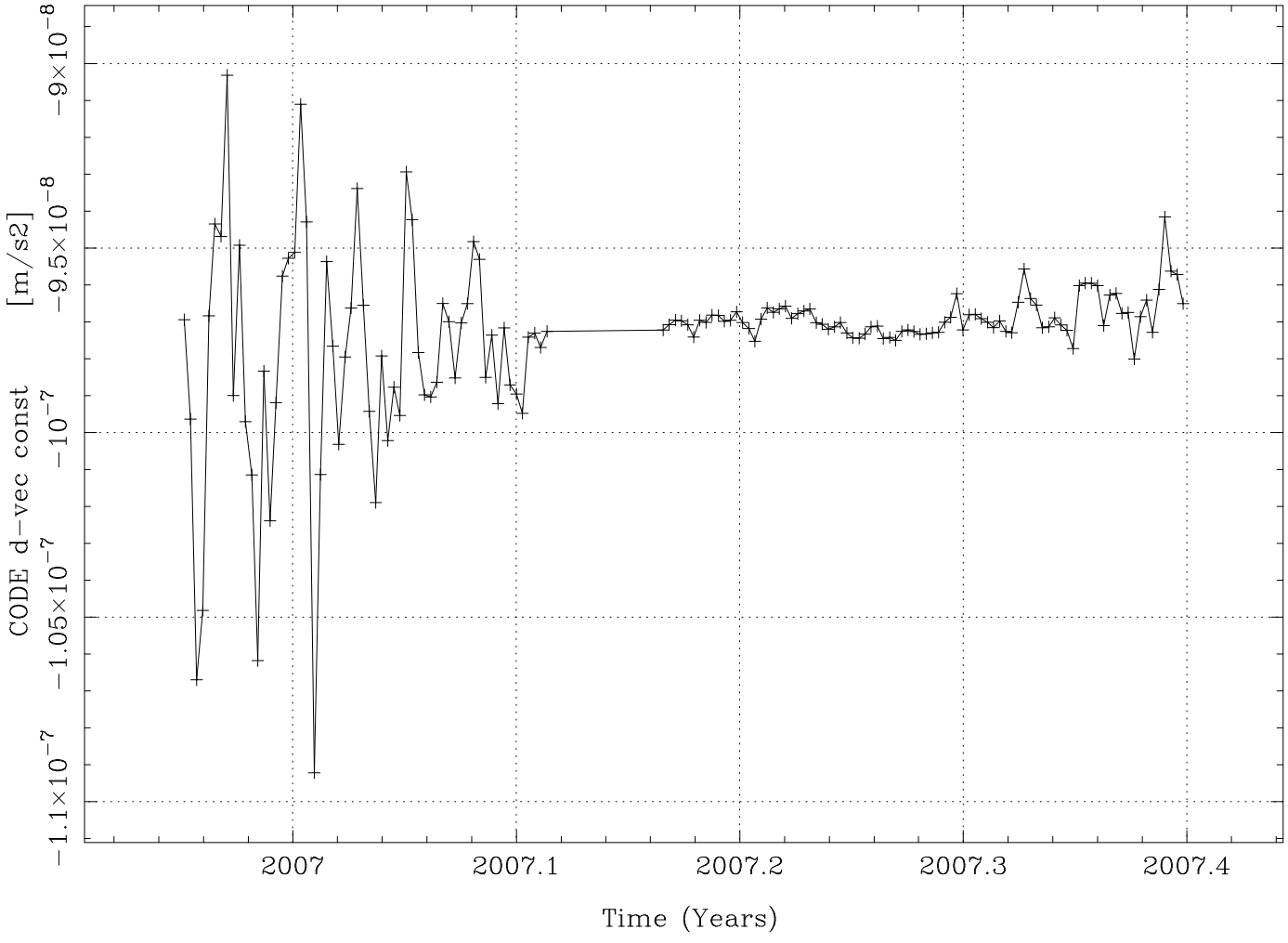
| Solution | Radial | Trans. | Cross | 3D-RMS | Typical RMS |
|---|---|---|---|---|---|
| micro vs. SLR | 93 | 510 | 396 | 652 | 377 |
| micro+SLR vs. SLR | 73 | 450 | 369 | 587 | 339 |
| micro+SLR vs. micro | 46 | 169 | 137 | 222 | 128 |

RMS [mm]

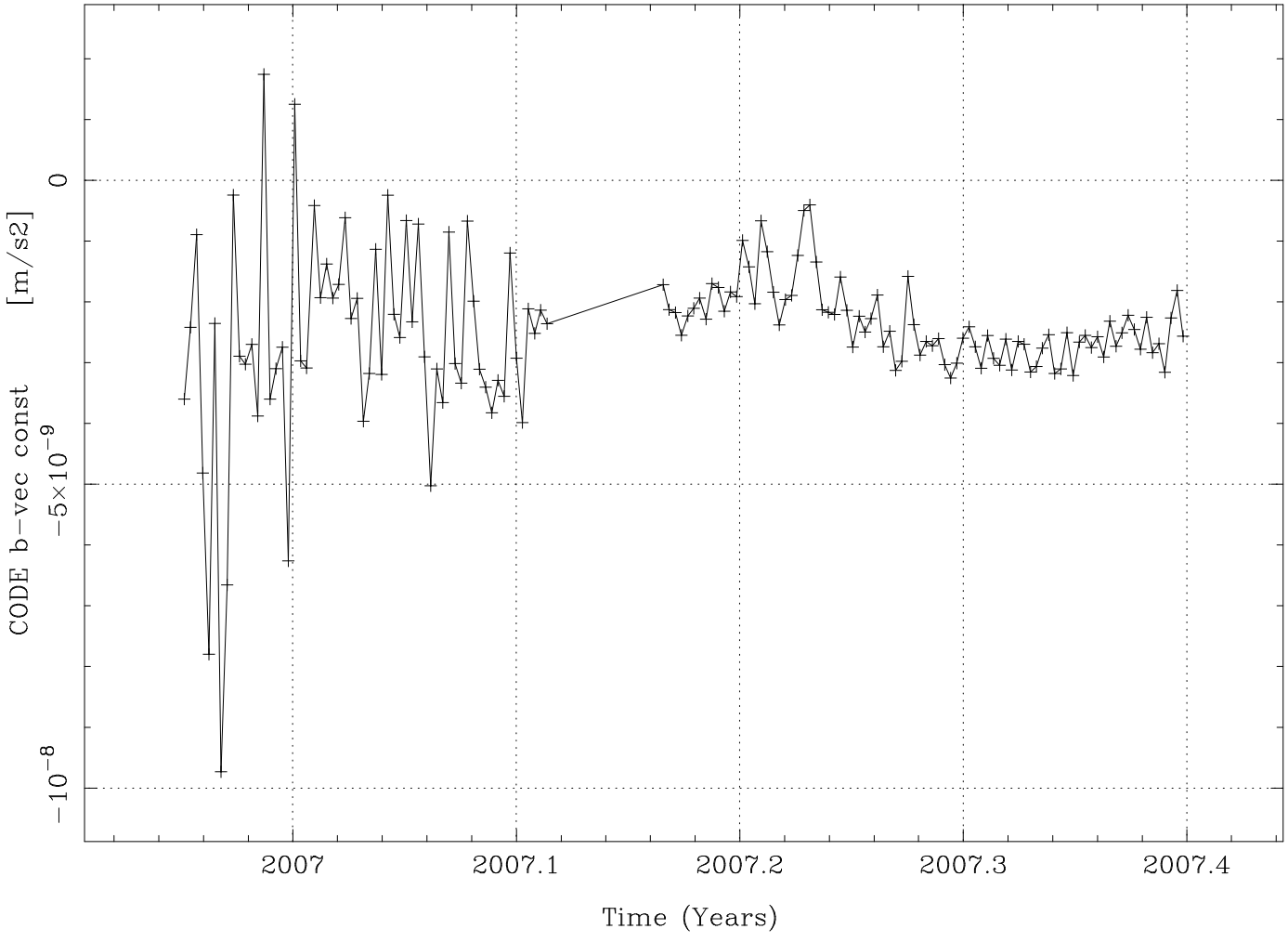
# Coordinate system of the solar pressure model



# Evolution of the constant solar radiation pressure term D0



# Evolution of the constant solar radiation pressure term B0



# Influence of the solar pressure parameter [mm]

| | D0Y0B0BP | | | | D0Y0B0 | | | |
|---|---|---|---|---|---|---|---|---|
| | 2d | 3d | 4d | 5d | 2d | 3d | 4d | 5d |
| Part 1 | 172 | 110 | 81 | 84 | 474 | 408 | 426 | 411 |
| Part 2 | 80 | 41 | 34 | 31 | 135 | 101 | 110 | 106 |

RMS [mm]

# Influence of the solar pressure parameter [mm]

| | D0Y0B0BP | | | | D0Y0B0 | | | |
|---|---|---|---|---|---|---|---|---|
| | 2d | 3d | 4d | 5d | 2d | 3d | 4d | 5d |
| Part 1 | 172 | 110 | 81 | 84 | 474 | 408 | 426 | 411 |
| Part 2 | 80 | 41 | 34 | 31 | 135 | 101 | 110 | 106 |

RMS [mm]

| | D0Y0B0DpBp | | | | D0Y0DpBp | | | |
|---|---|---|---|---|---|---|---|---|
| | 2d | 3d | 4d | 5d | 2d | 3d | 4d | 5d |
| Part 1 | 206 | 117 | 86 | 88 | 231 | 162 | 134 | 132 |
| Part 2 | 90 | 44 | 35 | 33 | 103 | 54 | 46 | 42 |

RMS [mm]

# Conclusion

- Considering the point that GIOVE-A is a test satellite the results are promising.
- The GIOVE-A signal quality expected from the simulations could be confirmed.
- The 13 GESS tracking network allow an orbit accuracy of approximately 0.2 m.
- The additional use of SLR observations increases the orbit accuracy from an internal consistency of 52 mm to 41 mm.
- A significant improvement of the orbit and the solar radiation pressure parameter after the outage could be identified.
- A significant non-zero value for the constant solar radiation pressure parameters in the B-axis could be identified.

# Acknowledgement

Many thanks to ESTEC which provided the GIOVE-A-RINEX-Data in the context of the GGSP-Project.

# Acknowledgement

Many thanks to ESTEC which provided the GIOVE-A-RINEX-Data in the context of the GGSP-Project.

Thank you for your attention!