# The Effect of SLR Tracking Scenarios to GNSS Satellites in a Combined GNSS/SLR Solution

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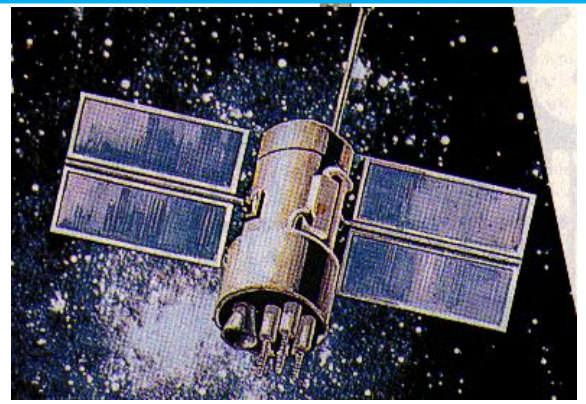
# Contents

# Introduction – Combining SLR+GNSS using space ties

- Creating a 7-day combined solution from microwave and SLR
  - Weighting observations SLR:GNSS with 2000:1



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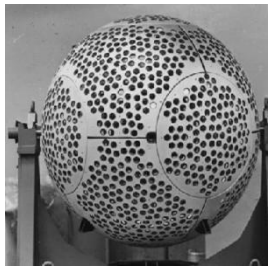
1-day NEQ from GNSS + 1-day NEQ from SLR

7X

Combine to 7-day NEQ

7-day SLR to LAGEOS and Etalon NEQ



7-day combined SLR+GNSS+LAGEOS NEQ

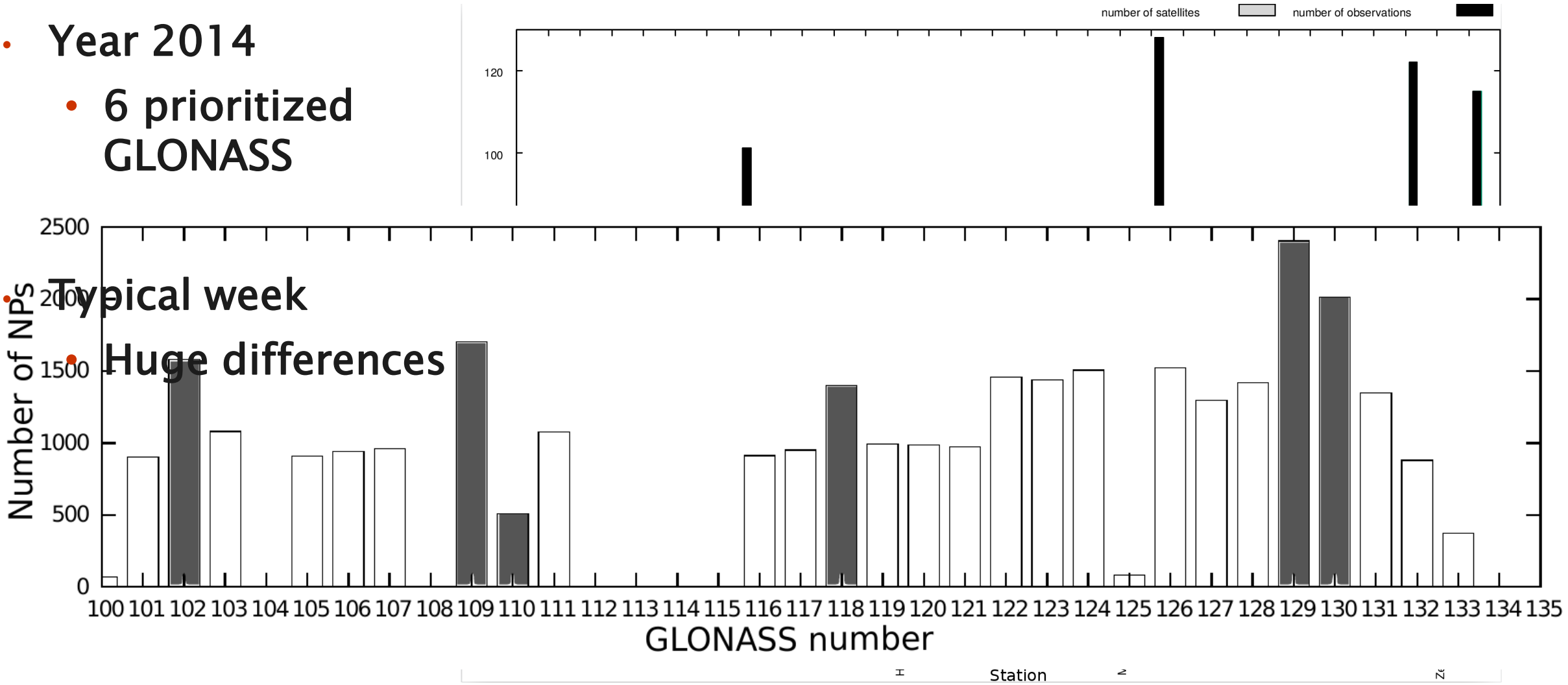
# Introduction – Simulation Setup

- Simulated NPs based on
  - 3D distance between station and satellite at given epoch
  - Satellite and station specific pseudo random noise

- Alternative scenarios
  - Based on real tracking activities of ILRS stations in given year
  - Epochs remain the same, targets exchanged
  - Concept of an altered ILRS priority list

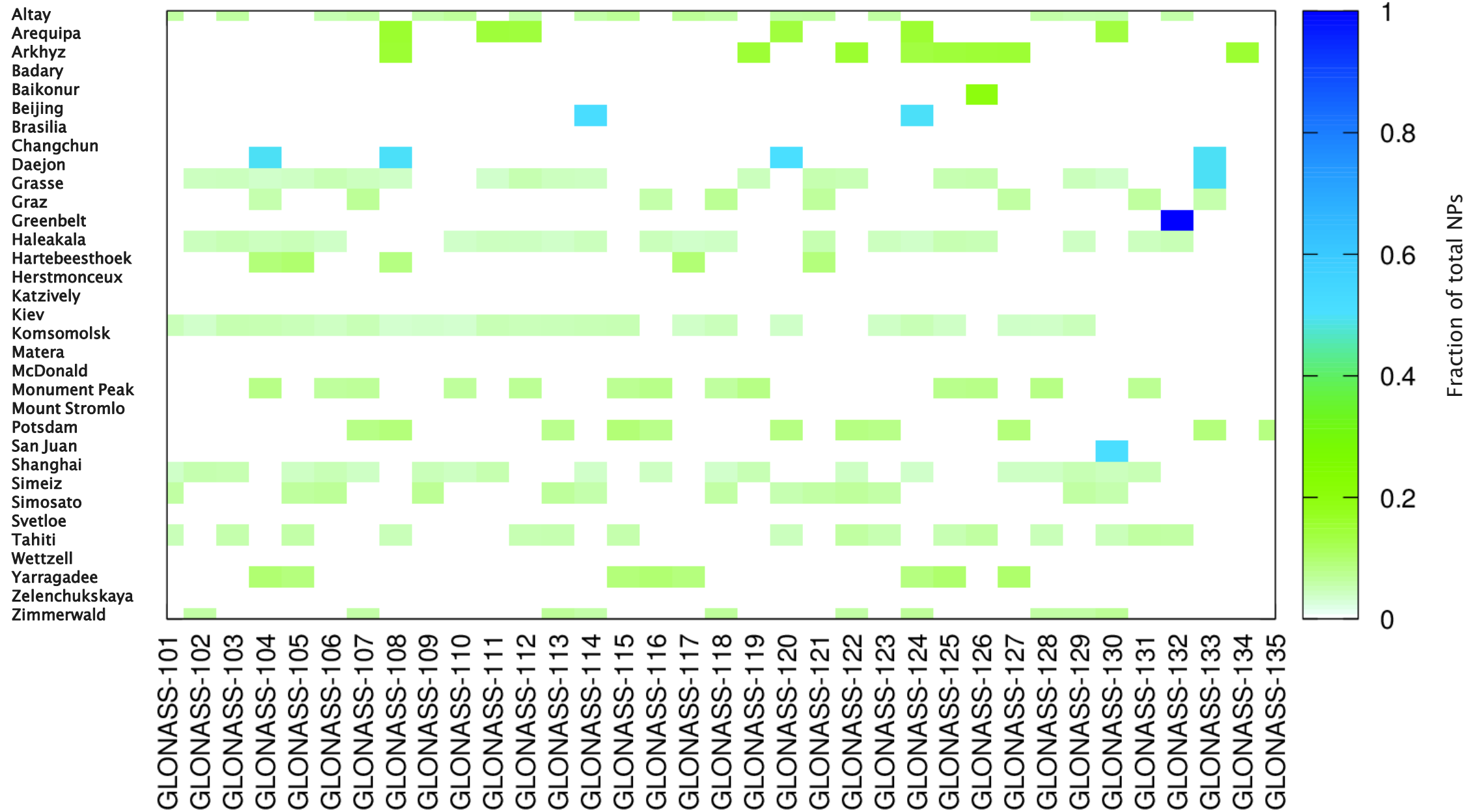
# Tracking scenarios – Real tracking activity in 2014 (REAL)

- Year 2014
  - 6 prioritized GLONASS
- Typical week
- Huge differences



# Tracking scenarios – Alternative Scenarios

- All GLONASS with equal priority (allGLONASS)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0.4
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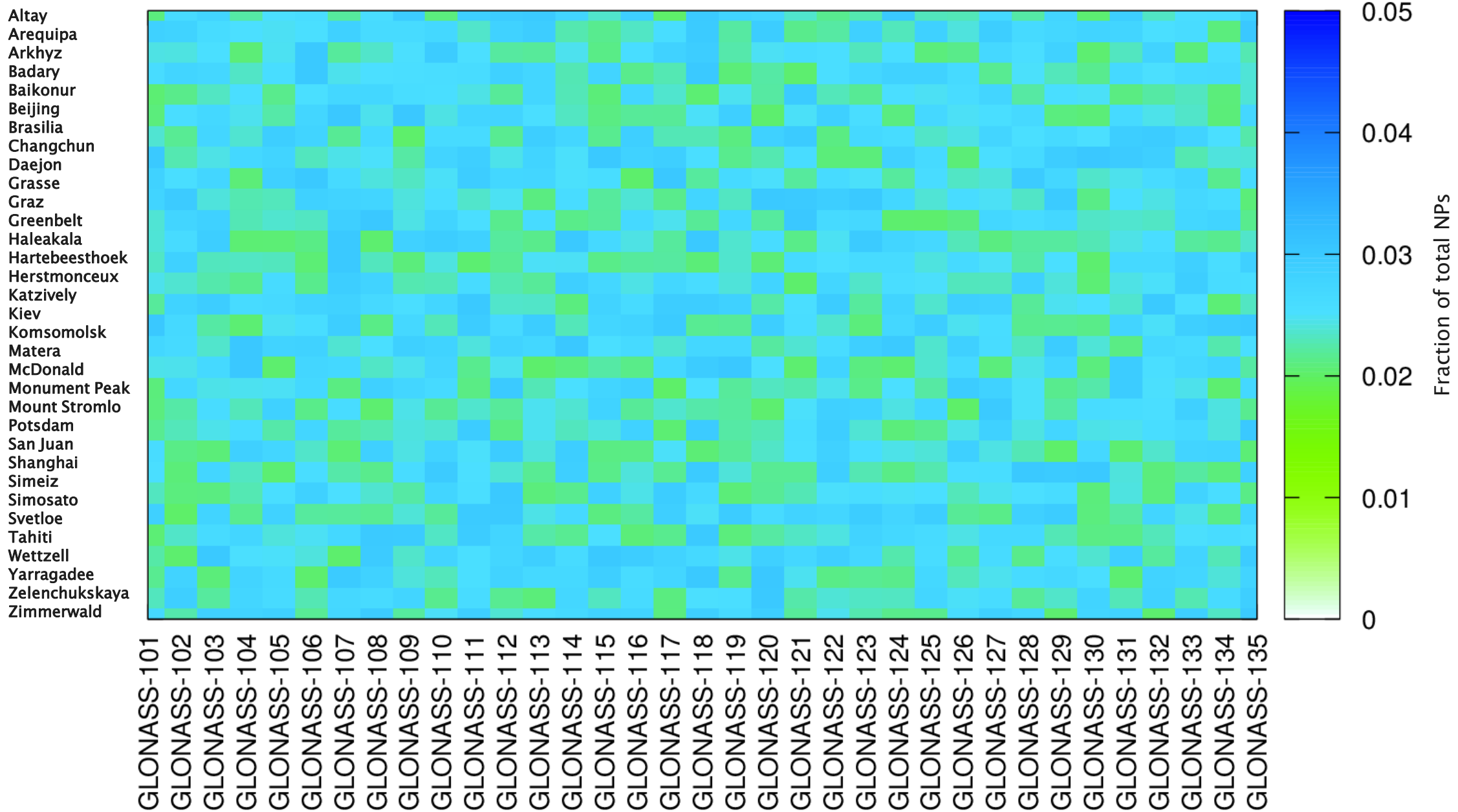
0
Fraction of total NPs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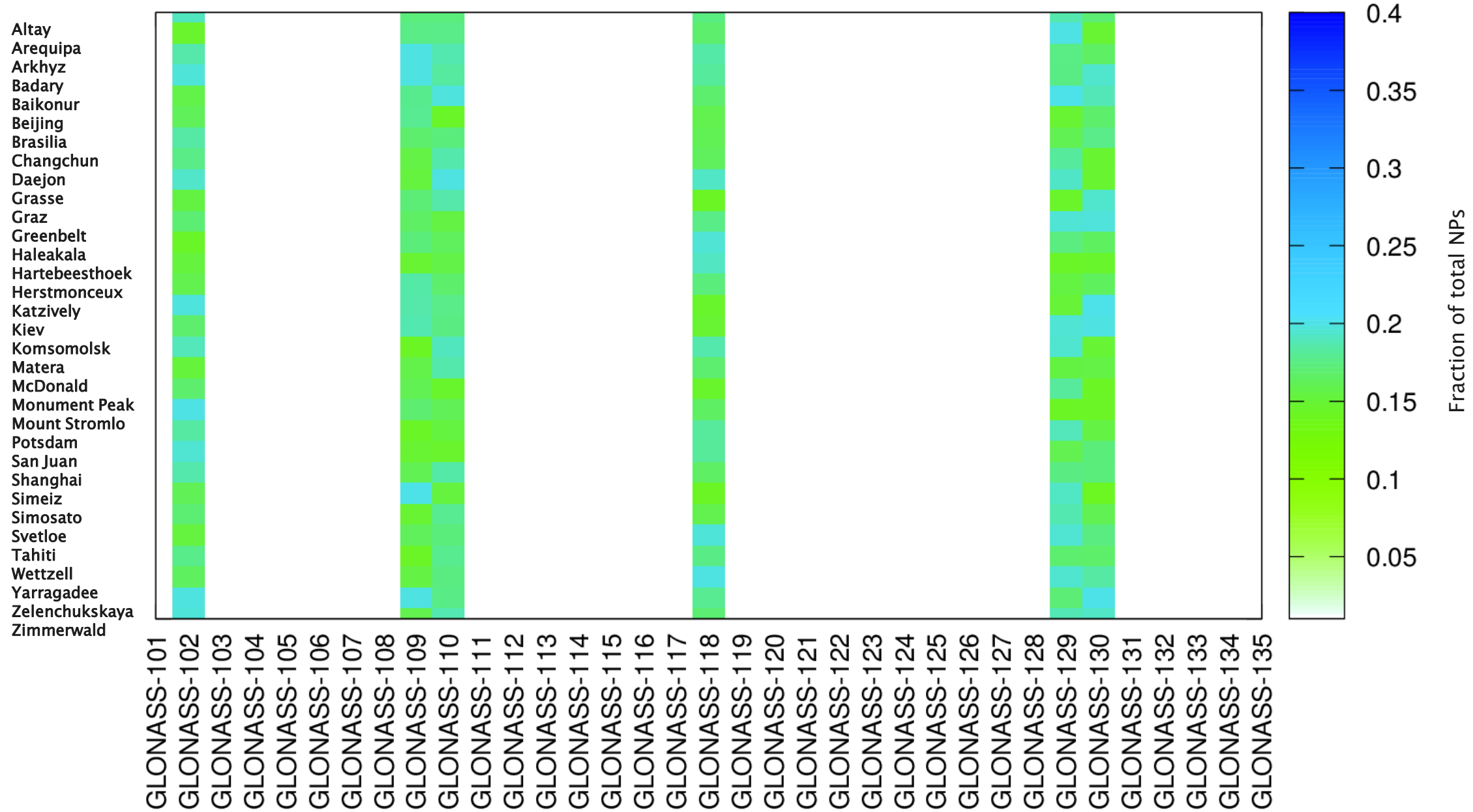
GLONASS-135
0.05
0.04
0.03
0.02
0.01
0
Fraction of total NPs

# Tracking scenarios – Alternative Scenarios

- All GLONASS with equal priority (allGLONASS)
- 2 GLONASS per orbital plane (2GLONASS)
  - GLONASS tracking to only those satellites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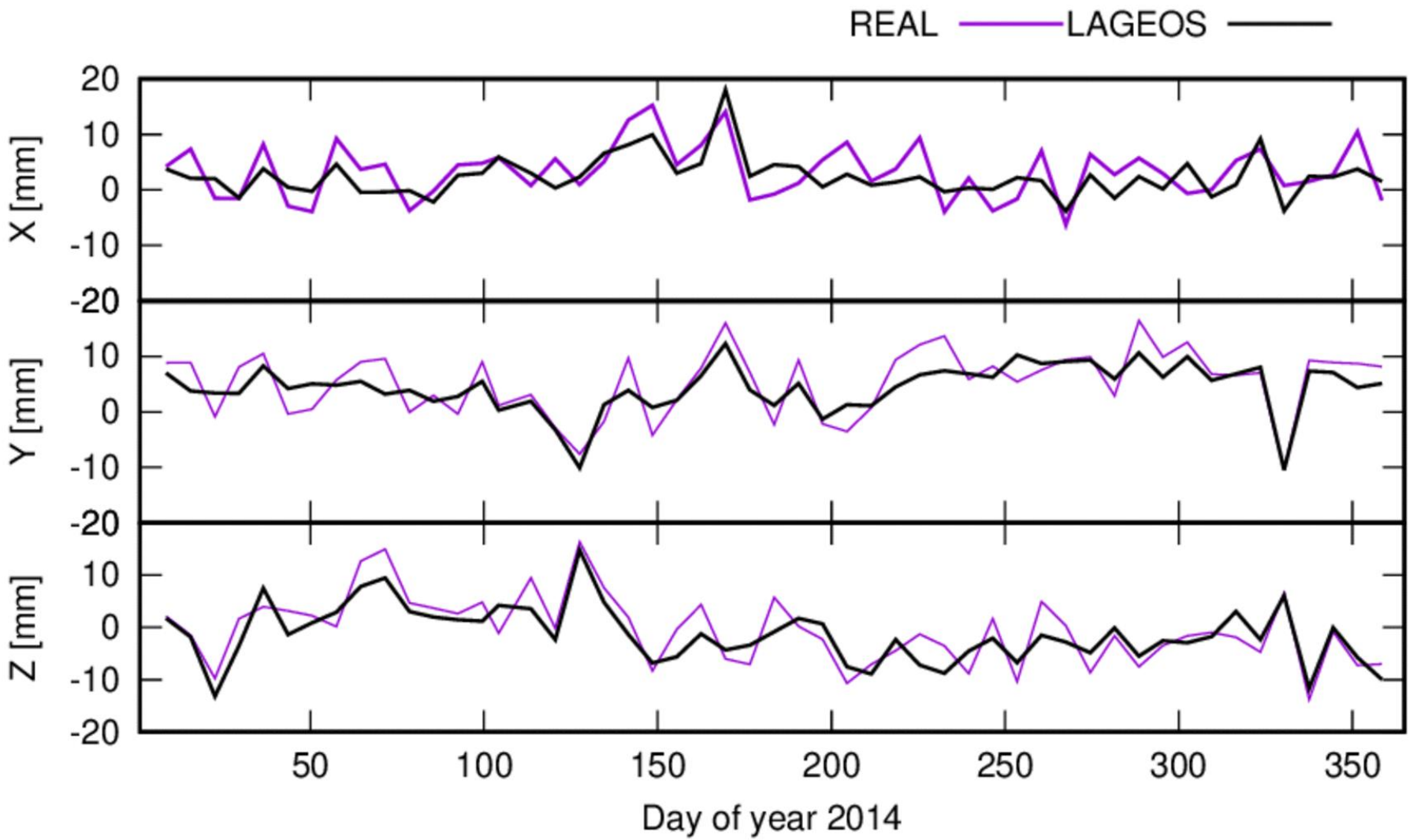
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
Fraction of total NPs

# Tracking scenarios – Alternative Scenarios

- All GLONASS with equal priority (allGLONASS)
- 2 GLONASS per orbital plane (2GLONASS)
  - GLONASS tracking to only those satellites
- Arranged tracking between European stations (EUROPE)
  - Six stations share the 6 prioritized satellites on a bi-weekly basis
- GPS and GLONASS equally (2SYSTEM)
  - Simulated retroreflectors on all GPS satellites

# Results – Geocenter Coordinates

- LAGEOS dominates
- Weekly Variations dominate
- Within 5mm of LAGEOS



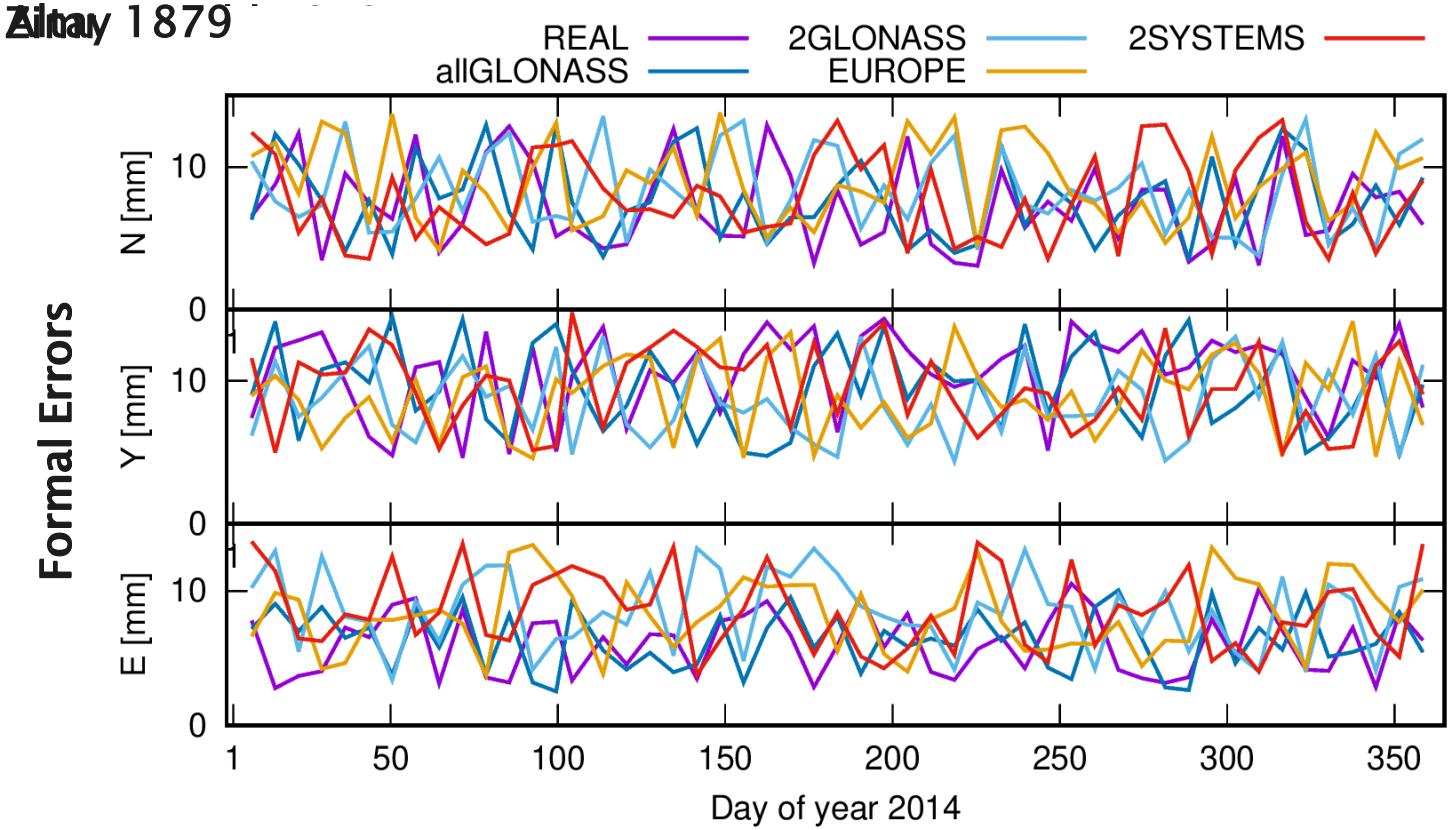
# Results – Station coordinates

- Consistent on a milimeter level
- RMS of station coordinates remains similar between all scenarios except 2SYSTEM.

| Parameter | REAL | allGLONASS | 2GLONASS | EUROPE | 2SYSTEM |
|---|---|---|---|---|---|
| **Zimmerwald (7810)** | | | | | |
| RMS X | 13.0 ± 9.1 mm | 15.0 ± 7.4 mm | 12.0 ± 5.0 mm | 12.2 ± 9.0 mm | 23.0 ± 8.7 mm |
| RMS Y | 8.0 ± 10.2 mm | 9.0 ± 9.3 mm | 6.0 ± 4.6 mm | 12.5 ± 6.0 mm | 16.0 ± 9.7 mm |
| RMS Z | 11.0 ± 7.2 mm | 10.2 ± 8.8 mm | 7.8 ± 5.6 mm | 13.3 ± 7.1 mm | 17.1 ± 9.0 mm |
| **Graz (7839)** | | | | | |
| RMS X | 16.0 ± 8.2 mm | 18.0 ± 8.9 mm | 14.0 ± 7.1 mm | 14.3 ± 7.8 mm | 25.1 ± 9.8 mm |
| RMS Y | 18.0 ± 9.4 mm | 17.4 ± 9.3 mm | 12.0 ± 7.6 mm | 15.9 ± 4.5 mm | 22.5 ± 11.7 mm |
| RMS Z | 14.0 ± 8.1 mm | 13.3 ± 9.3 mm | 12.5 ± 8.6 mm | 14.3 ± 6.7 mm | 19.0 ± 9.8 mm |
| **Yarragadee (7090)** | | | | | |
| RMS X | 16.0 ± 4.5 mm | 13.0 ± 3.9 mm | 14.0 ± 4.5 mm | 11.0 ± 5.7 mm | 18.0 ± 7.3 mm |
| RMS Y | 14.1 ± 4.0 mm | 14.0 ± 5.3 mm | 12.2 ± 6.0 mm | 12.8 ± 4.3 mm | 17.3 ± 6.6 mm |
| RMS Z | 12.1 ± 6.7 mm | 11.7 ± 6.5 mm | 14.8 ± 6.5 mm | 13.4 ± 5.1 mm | 18.2 ± 8.7 mm |
| **Altay (1879)** | | | | | |
| RMS X | 19.3 ± 6.1 mm | 18.7 ± 6.2 mm | 21.0 ± 5.8 mm | 19.0 ± 5.7 mm | 21.3 ± 7.1 mm |
| RMS Y | 18.8 ± 5.8 mm | 19.0 ± 5.9 mm | 20.1 ± 6.2 mm | 19.8 ± 6.4 mm | 19.6 ± 6.6 mm |
| RMS Z | 18.7 ± 6.6 mm | 19.0 ± 6.3 mm | 17.9 ± 6.4 mm | 19.3 ± 5.8 mm | 18.9 ± 6.2 mm |

# Results – Station coordinates

- Consistent on a milimeter level
- RMS of station coordinates remains similar between all scenarios except 2SYSTEM.
- Formal errors:
  - More difference for stations with more NPs
  - allGLONASS similar to REAL, lowest errors



# Results – Earth Rotation Parameters

- ERPs favour a balanced distribution
- 2SYSTEMS performs worst
  - Noisier SLR observations now also affect GPS

| Parameter | REAL | allGLONASS | 2GLONASS | EUROPE | 2SYSTEMS |
|---|---|---|---|---|---|
| **ERPs diff.** | | | | | |
| **X-Pole** | $0.50 \pm 1.10\,\mu as$ | $0.10 \pm 0.50\,\mu as$ | $0.40 \pm 1.30\,\mu as$ | $0.40 \pm 1.20\,\mu as$ | $0.30 \pm 2.30\,\mu as$ |
| **Y-Pole** | $0.60 \pm 1.00\,\mu as$ | $0.40 \pm 0.90\,\mu as$ | $0.60 \pm 1.10\,\mu as$ | $0.50 \pm 0.80\,\mu as$ | $0.90 \pm 1.80\,\mu as$ |
| **ERPs formal err.** | | | | | |
| **X-Pole** | $2.00 \pm 2.10\,\mu as$ | $1.90 \pm 1.00\,\mu as$ | $2.90 \pm 1.50\,\mu as$ | $2.00 \pm 0.90\,\mu as$ | $2.90 \pm 2.40\,\mu as$ |
| **Y-Pole** | $2.10 \pm 1.90\,\mu as$ | $1.70 \pm 1.10\,\mu as$ | $2.30 \pm 1.80\,\mu as$ | $1.90 \pm 1.00\,\mu as$ | $3.00 \pm 2.30\,\mu as$ |

# Conclusions

- Target selection is not as relevant as the total number and distribution of available NPs
- Station coordinates:
  - All scenarios have similar RMS except 2SYSTEMS
  - Formal errors correlate with the availability of NPs
- Earth Rotation Parameters:
  - Even distribution is beneficial
  - Possibly not enough NPs for 2SYSTEM
- Geocenter Coordinates:
  - Weekly variations larger than difference between scenarios
  - LAGEOS has main contribution
  - Improved in all scenarios over GNSS only