# Aspects of Global Multi–GNSS Processing

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# Outline

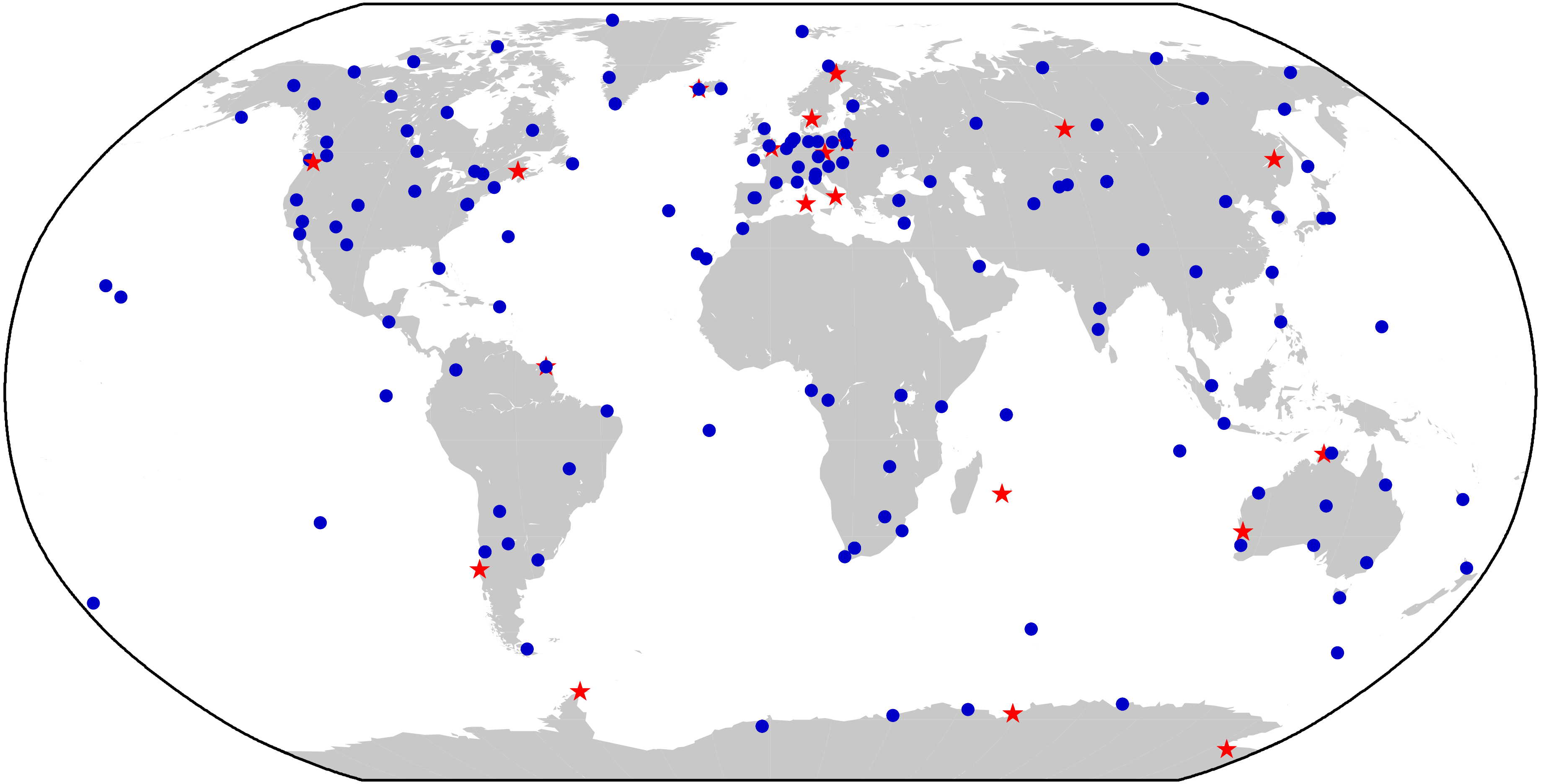
## Aspects of Global Multi–GNSS Processing:

1. Development of the IGS multi–GNSS network
2. Orbit characteristics for the individual GNSS
3. Impact of adding GLONASS to GPS measurements
   - on global parameters
   - for navigation purposes
4. Summary and Outlook

# Development of the IGS multi–GNSS network

Distribution of the combined GPS/GLONASS receivers in the IGS–network

status: July 2003 (day of year 2003:182)

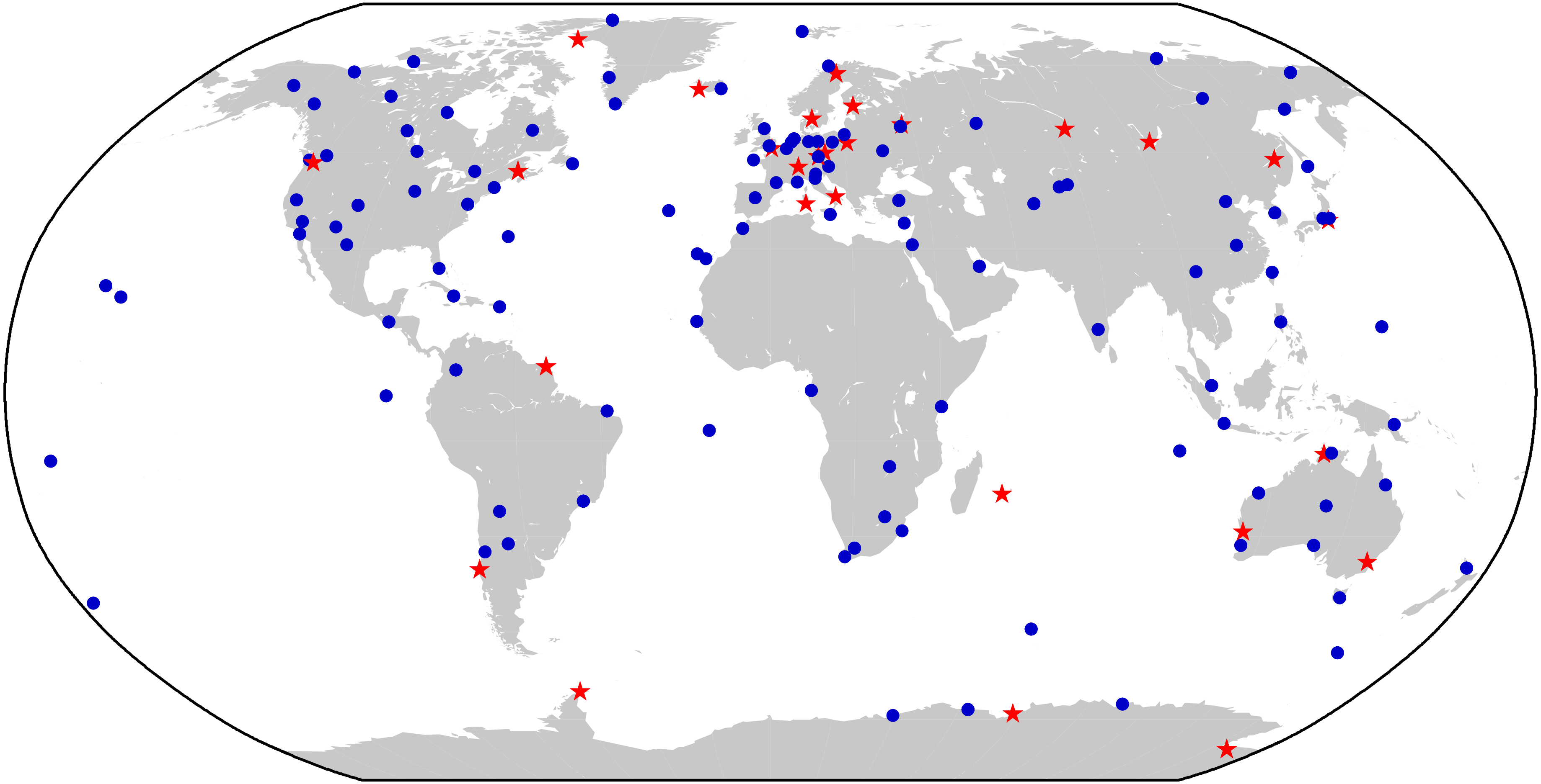


Receivers tracking: ★ GPS/GLONASS (21) • only GPS (137)

# Development of the IGS multi–GNSS network

Distribution of the combined GPS/GLONASS receivers in the IGS–network

status: February 2004 (day of year 2004:044)

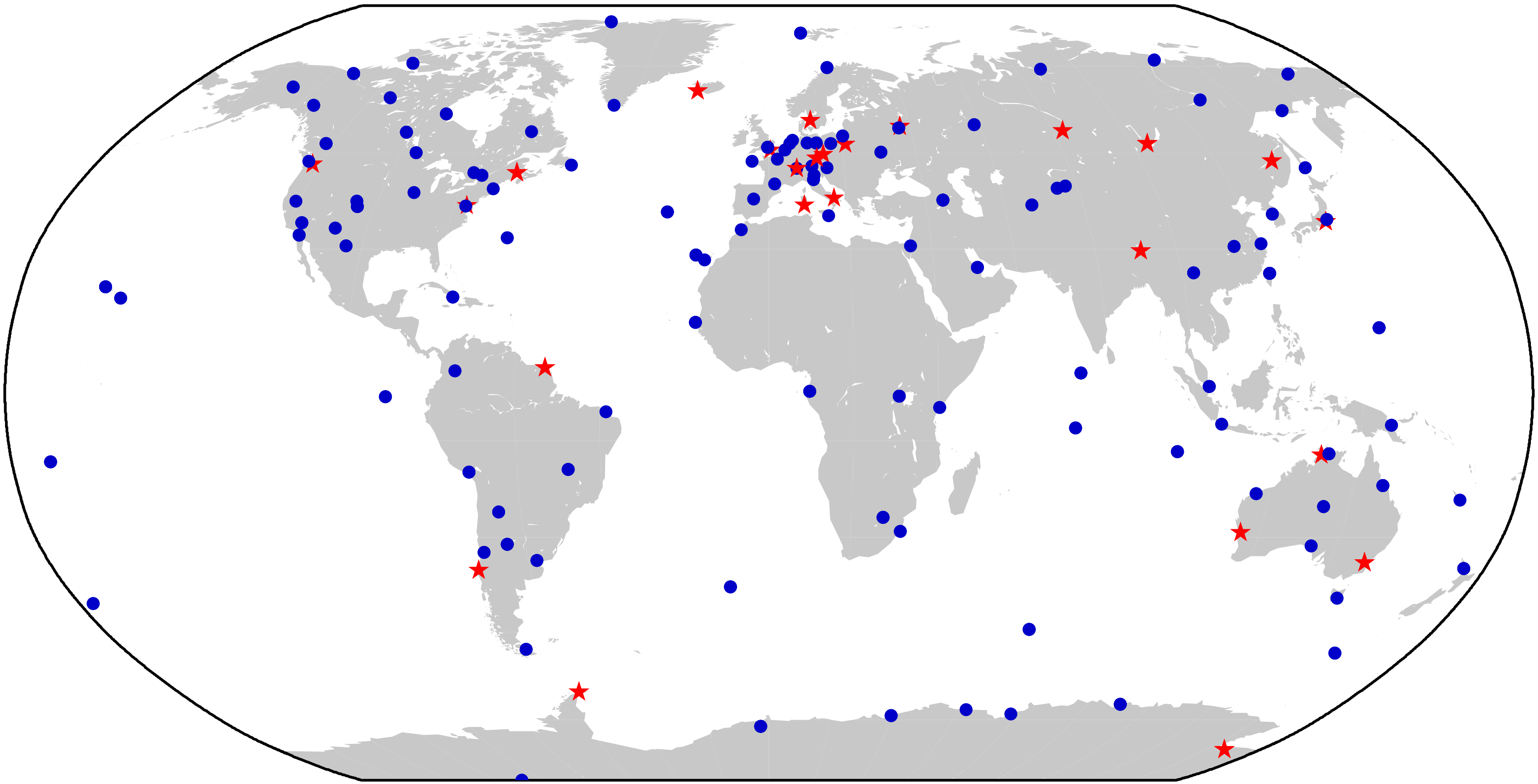


Receivers tracking: ★ GPS/GLONASS (28) • only GPS (117)

# Development of the IGS multi–GNSS network

Distribution of the combined GPS/GLONASS receivers in the IGS–network

status: May 2005 (day of year 2005:128)

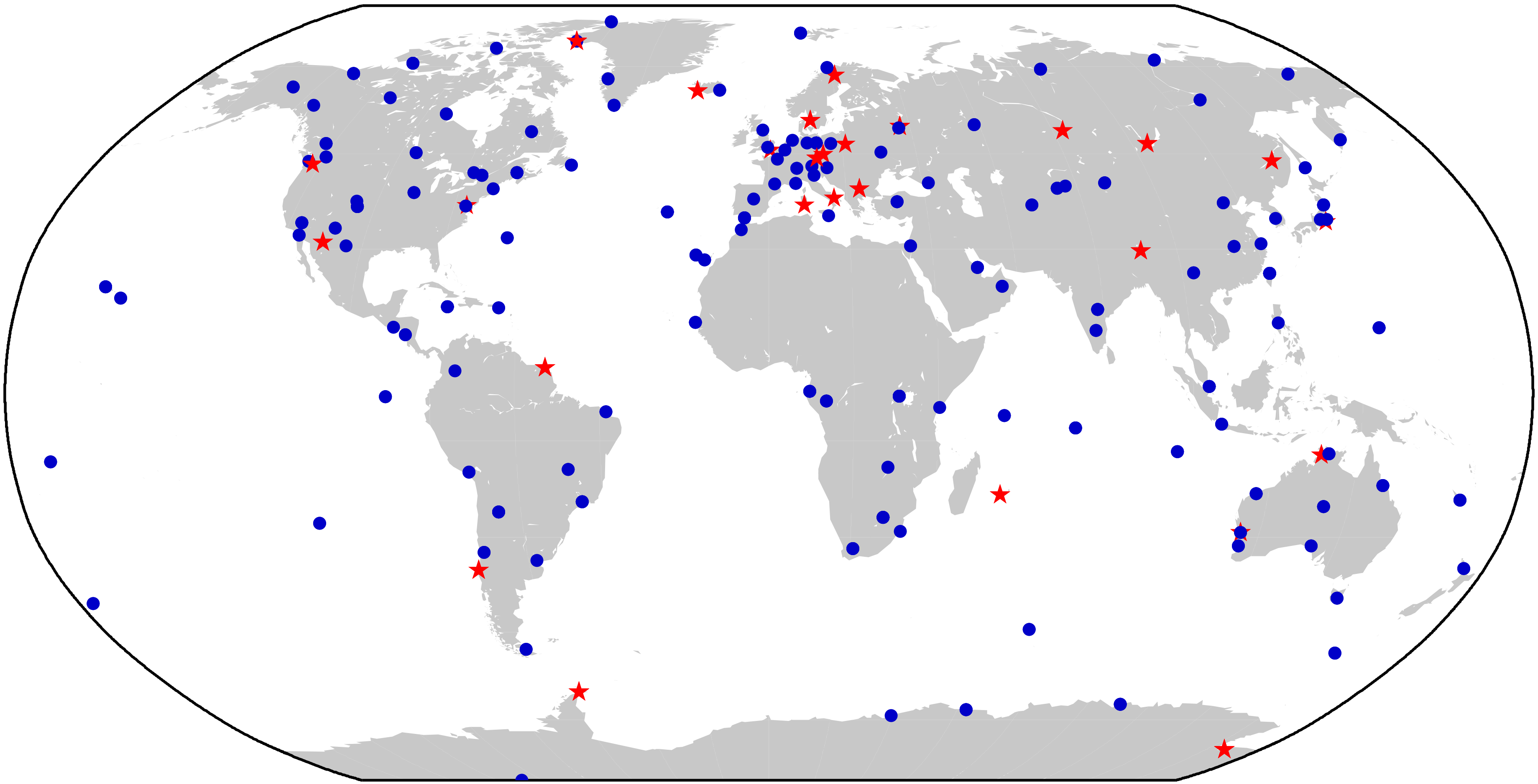


Receivers tracking: ★ GPS/GLONASS (27) • only GPS (117)

# Development of the IGS multi–GNSS network

Distribution of the combined GPS/GLONASS receivers in the IGS–network

status: August 2006 (day of year 2006:233)

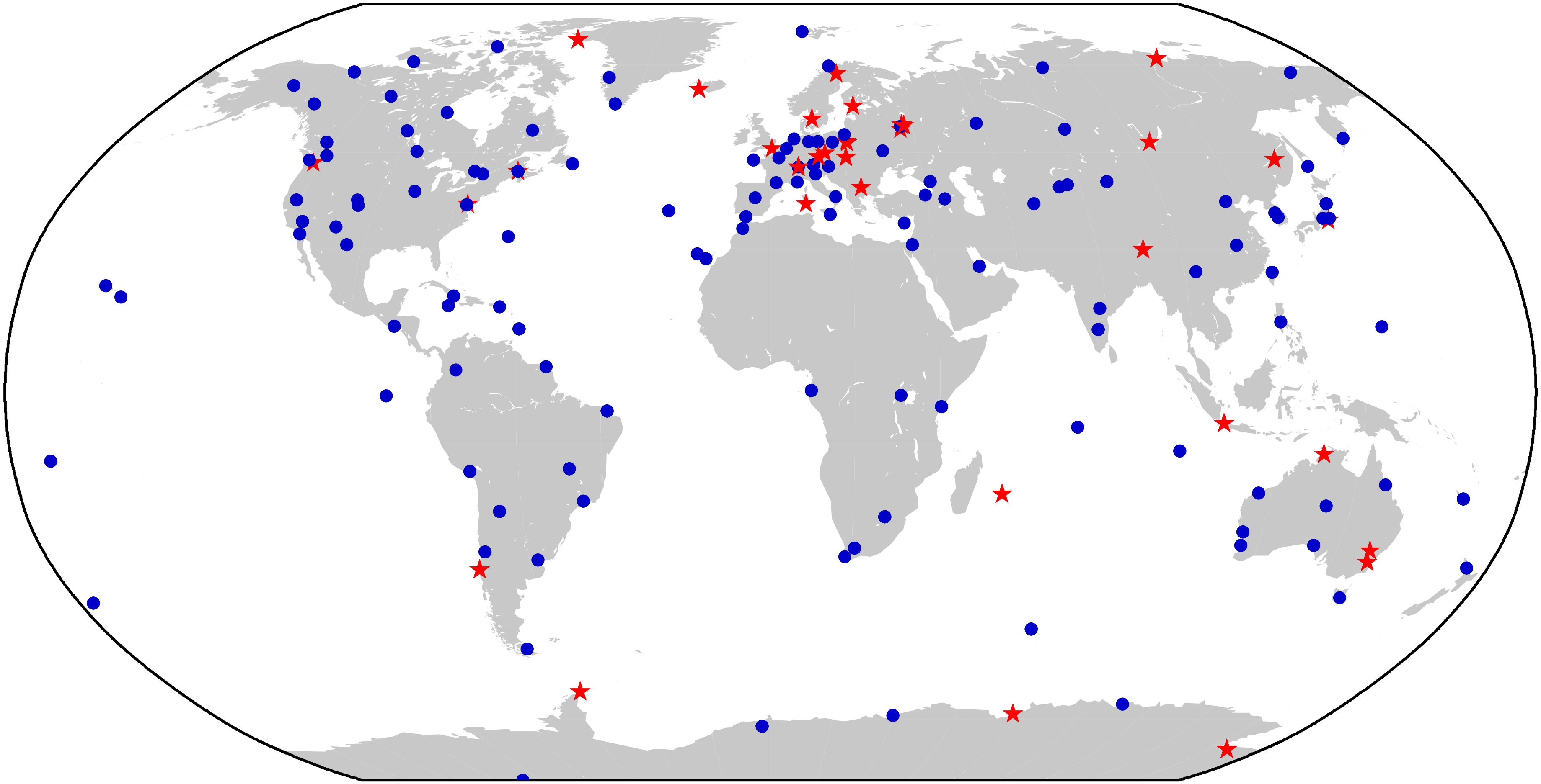


Receivers tracking: ★ GPS/GLONASS (28) ● only GPS (135)

# Development of the IGS multi–GNSS network

Distribution of the combined GPS/GLONASS receivers in the IGS–network

status: July 2007 (day of year 2007:191)

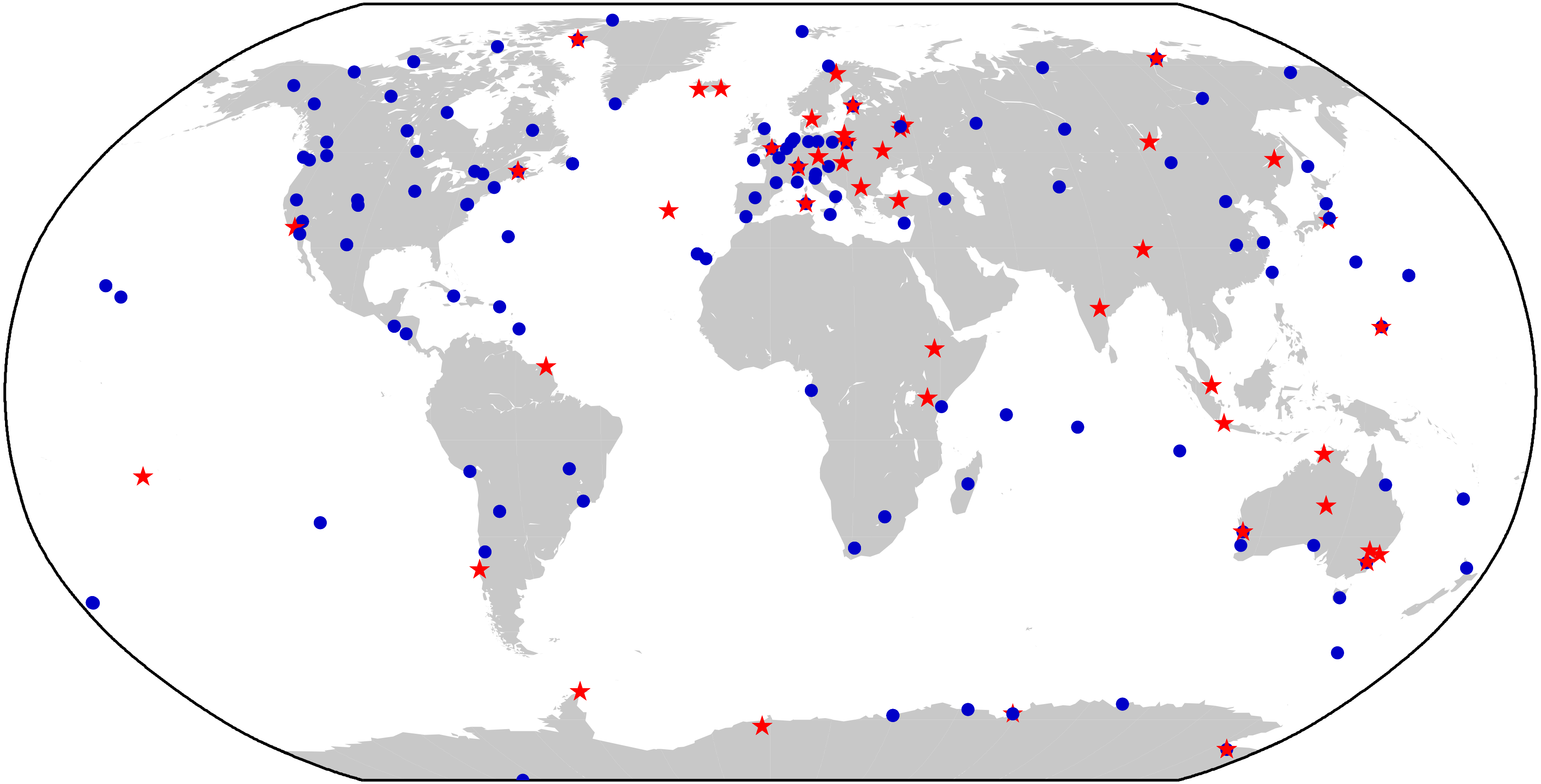


Receivers tracking: ★ GPS/GLONASS (36) • only GPS (127)

# Development of the IGS multi–GNSS network

Distribution of the combined GPS/GLONASS receivers in the IGS–network

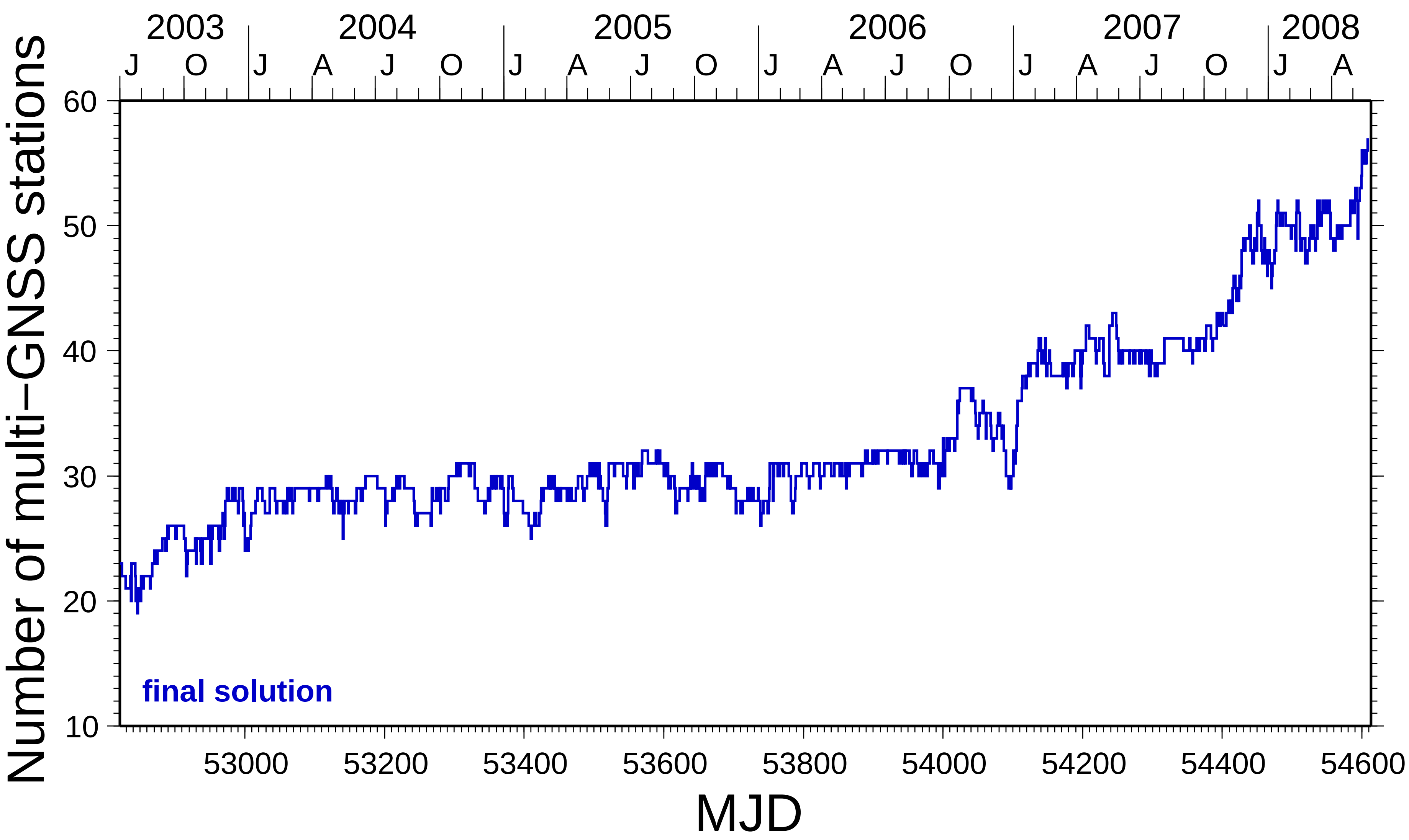
status: May 2008 (day of year 2008:140)



Receivers tracking: ★ GPS/GLONASS (53) ● only GPS (120)

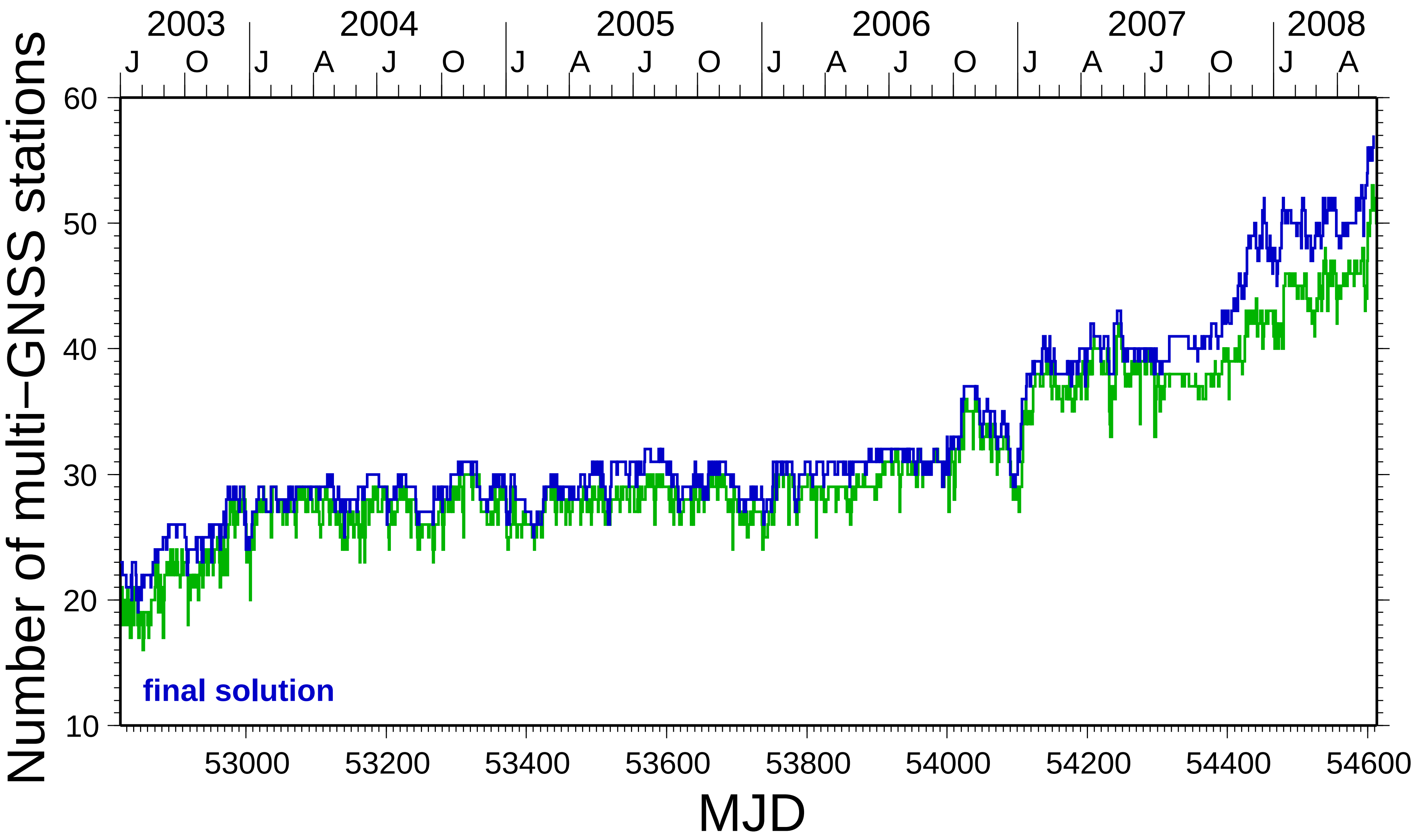
# Development of the IGS multi–GNSS network

Number of the combined GPS/GLONASS receivers in the IGS–network



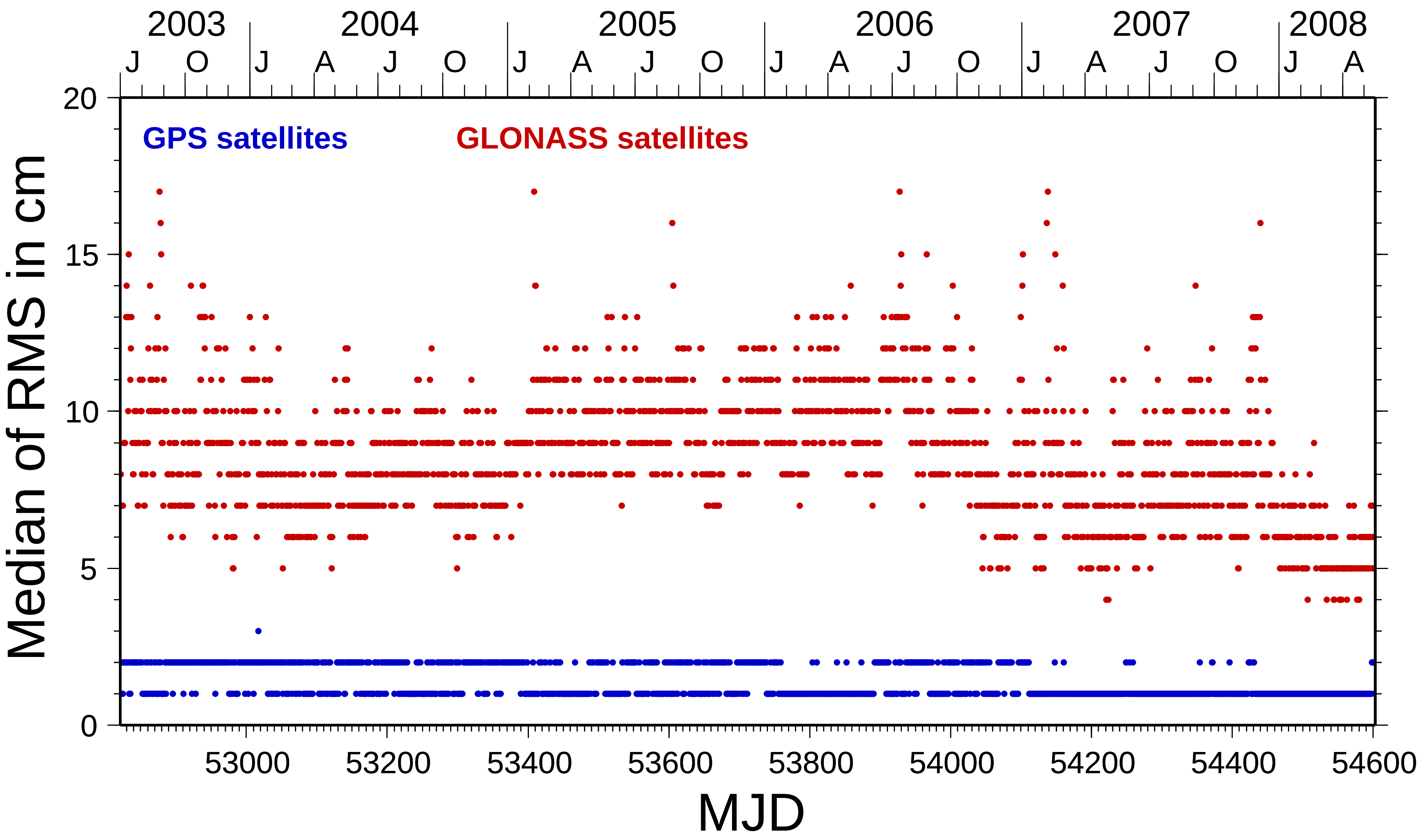
# Development of the IGS multi–GNSS network

Number of the combined GPS/GLONASS receivers in the IGS–network

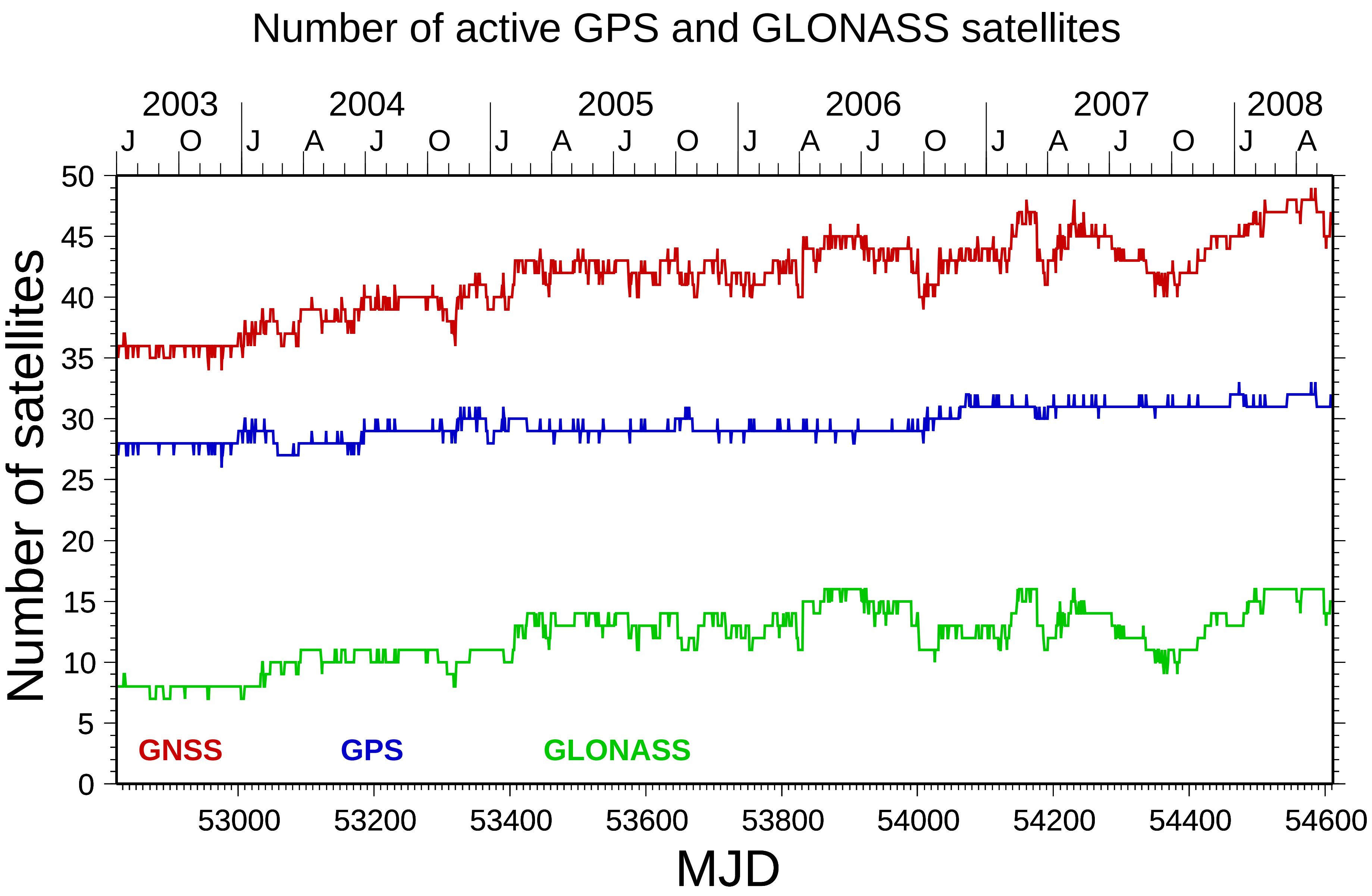


# GPS/GLONASS Orbit Comparison

Development of GLONASS satellite orbit accuracy provided by CODE



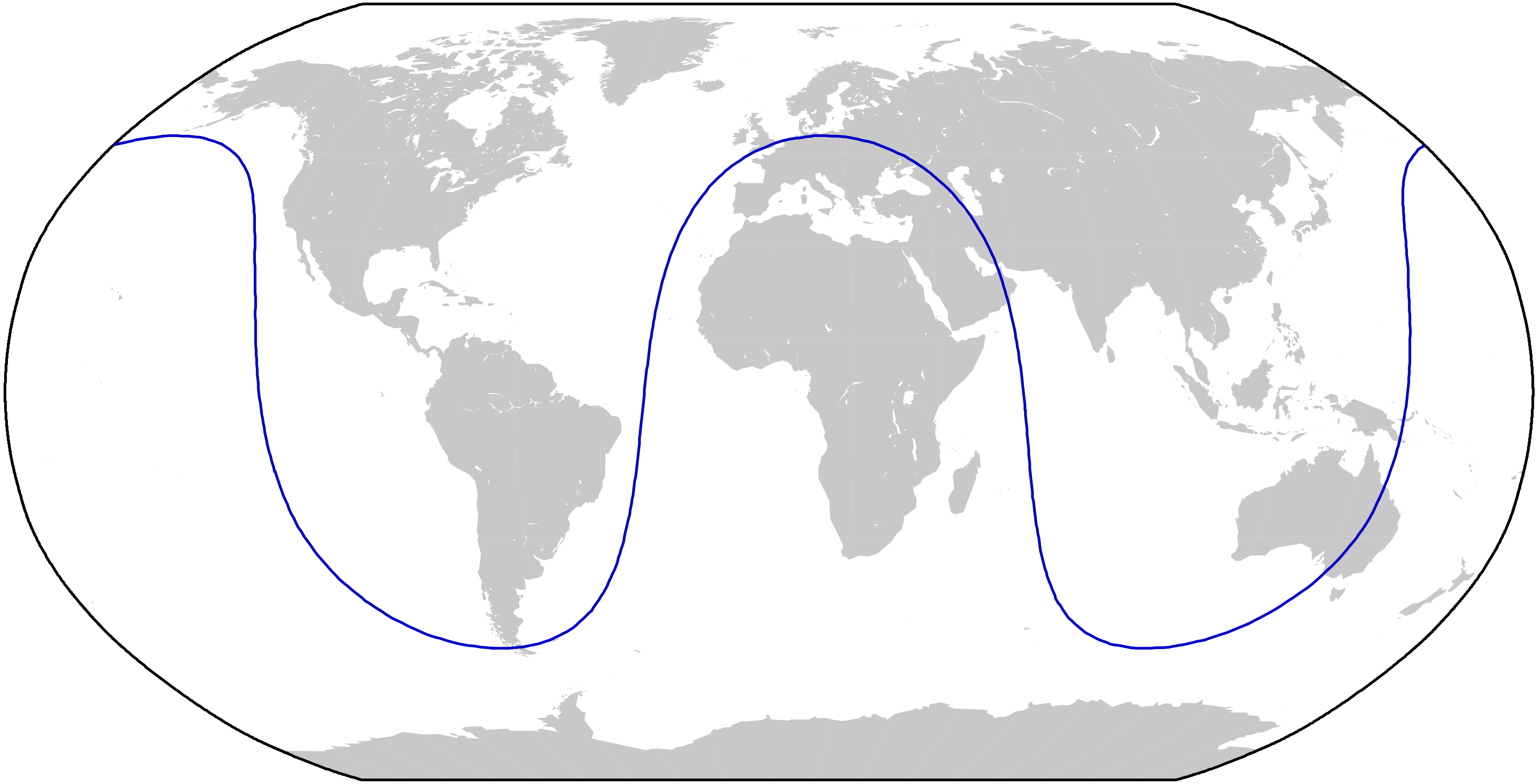
# GPS/GLONASS Orbit Comparison



# GPS/GLONASS Orbit Characteristics

## Ground track for the GPS constellation

Ground track for G06 for one day

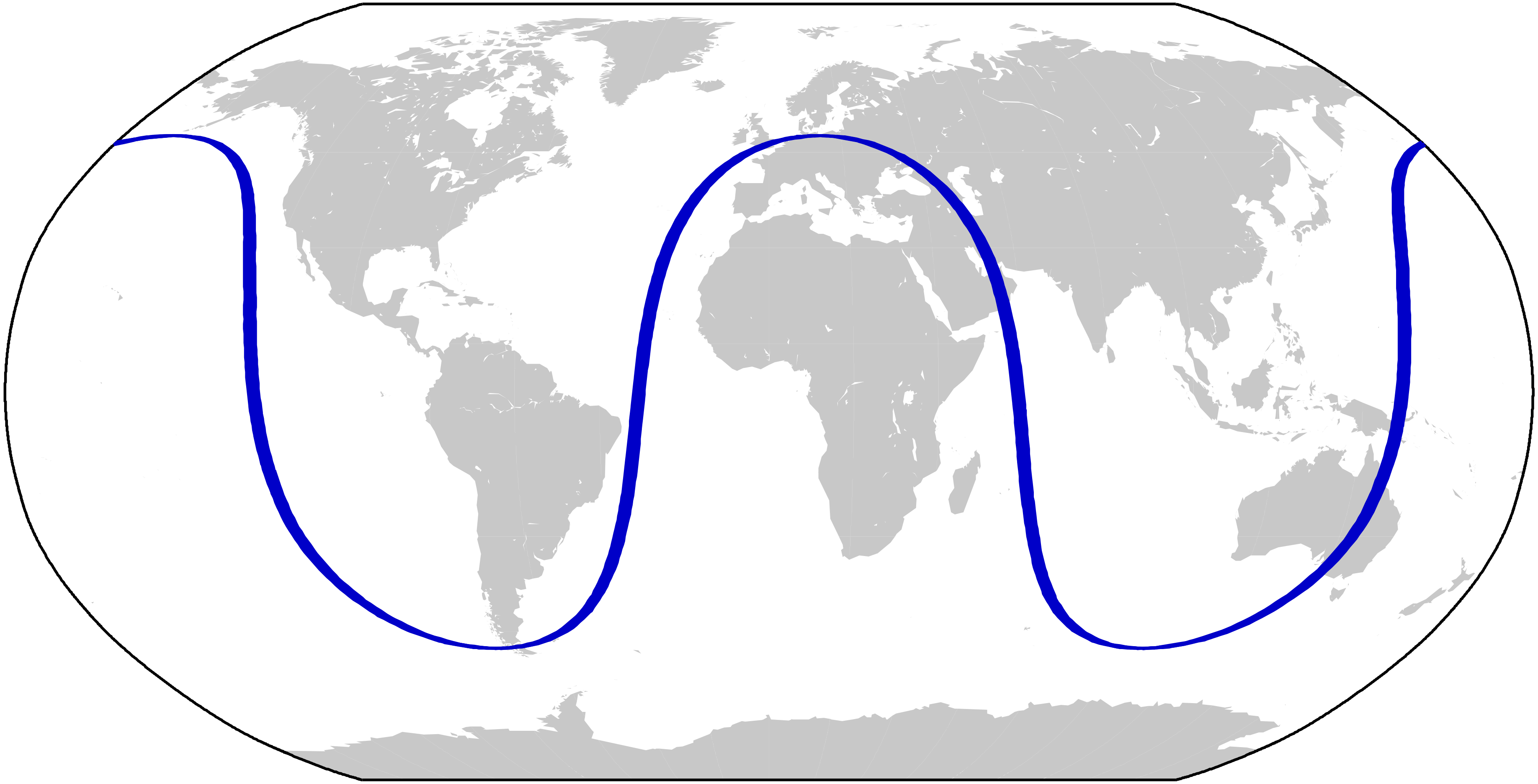


day of year 2008:060

# GPS/GLONASS Orbit Characteristics

Ground track for the GPS constellation

Ground track for G06 for ten days

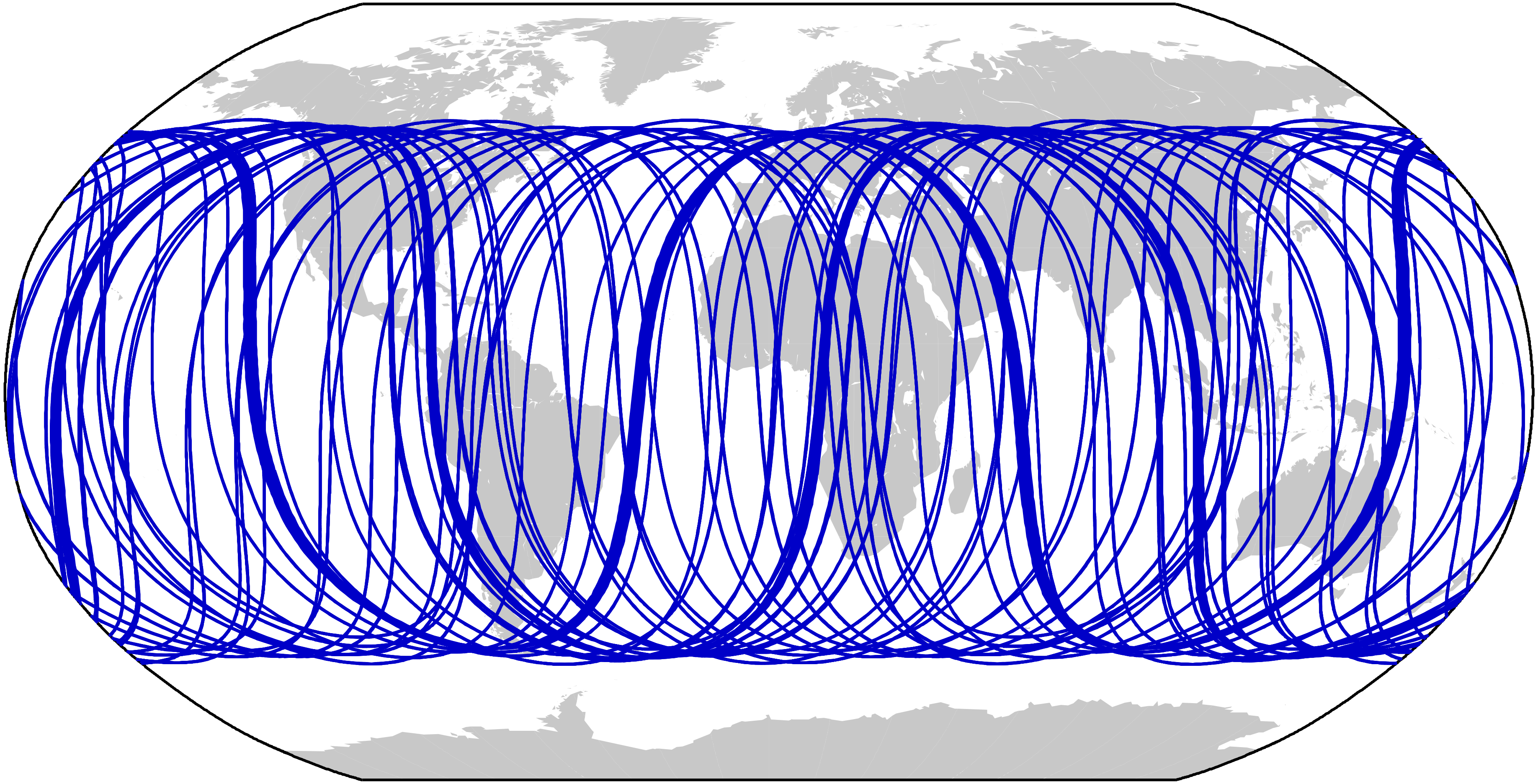


day of year 2008:060 to 069

# GPS/GLONASS Orbit Characteristics

Ground track for the GPS constellation

Ground track for all satellites for ten days

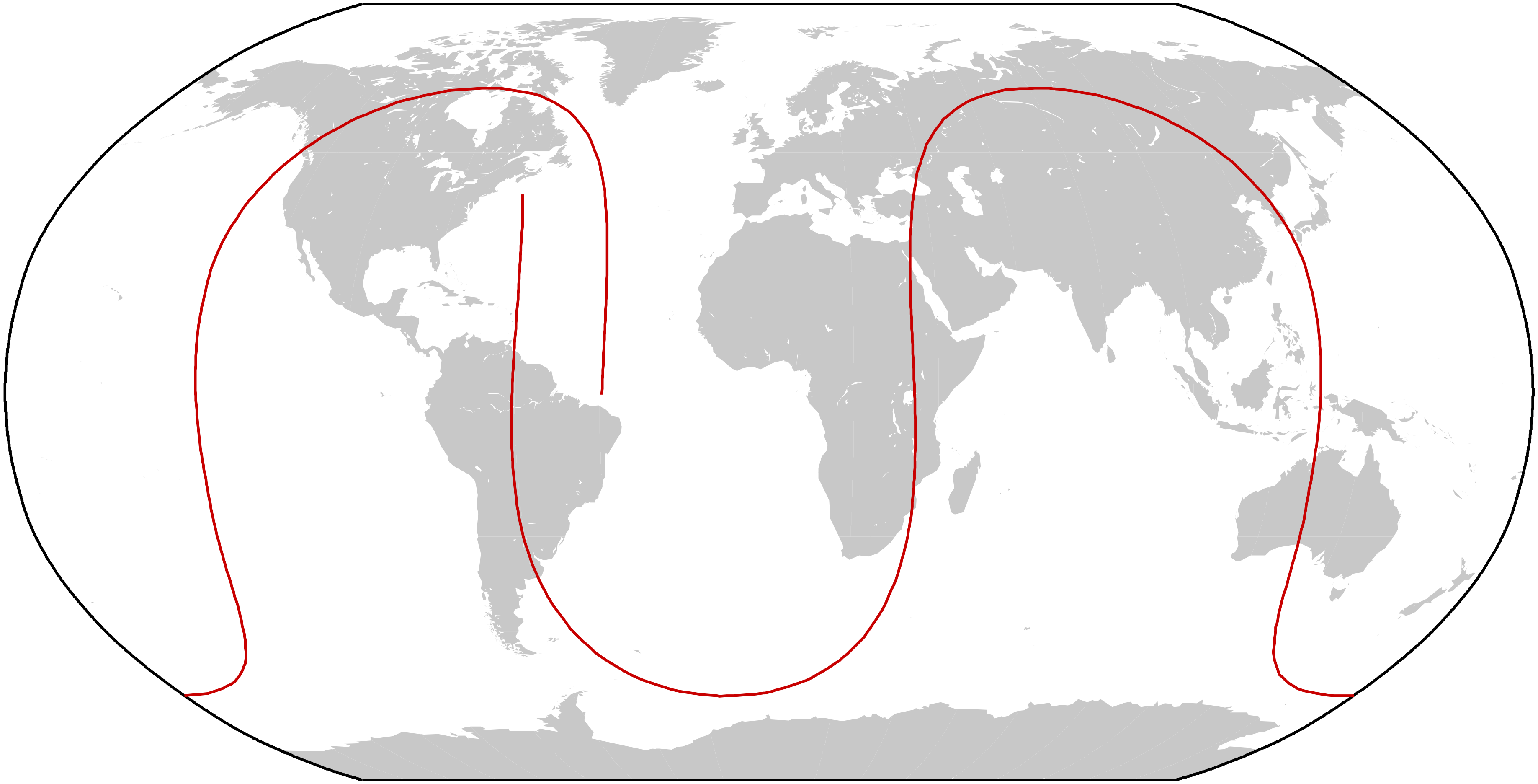


day of year 2008:060 to 069

# GPS/GLONASS Orbit Characteristics

Ground track for the GLONASS constellation

Ground track for R04 for one day

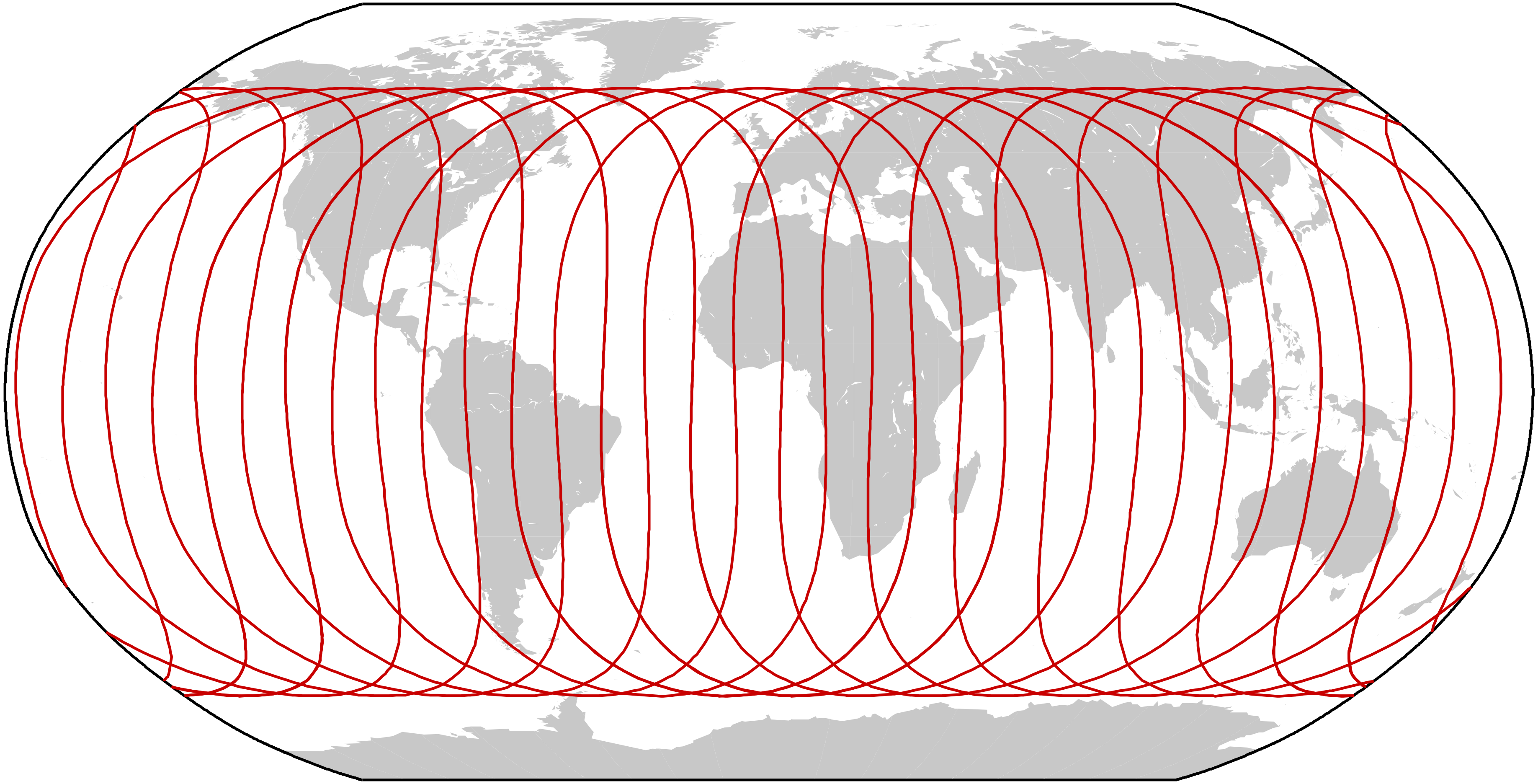


day of year 2008:060

# GPS/GLONASS Orbit Characteristics

Ground track for the GLONASS constellation

Ground track for R04 for ten days

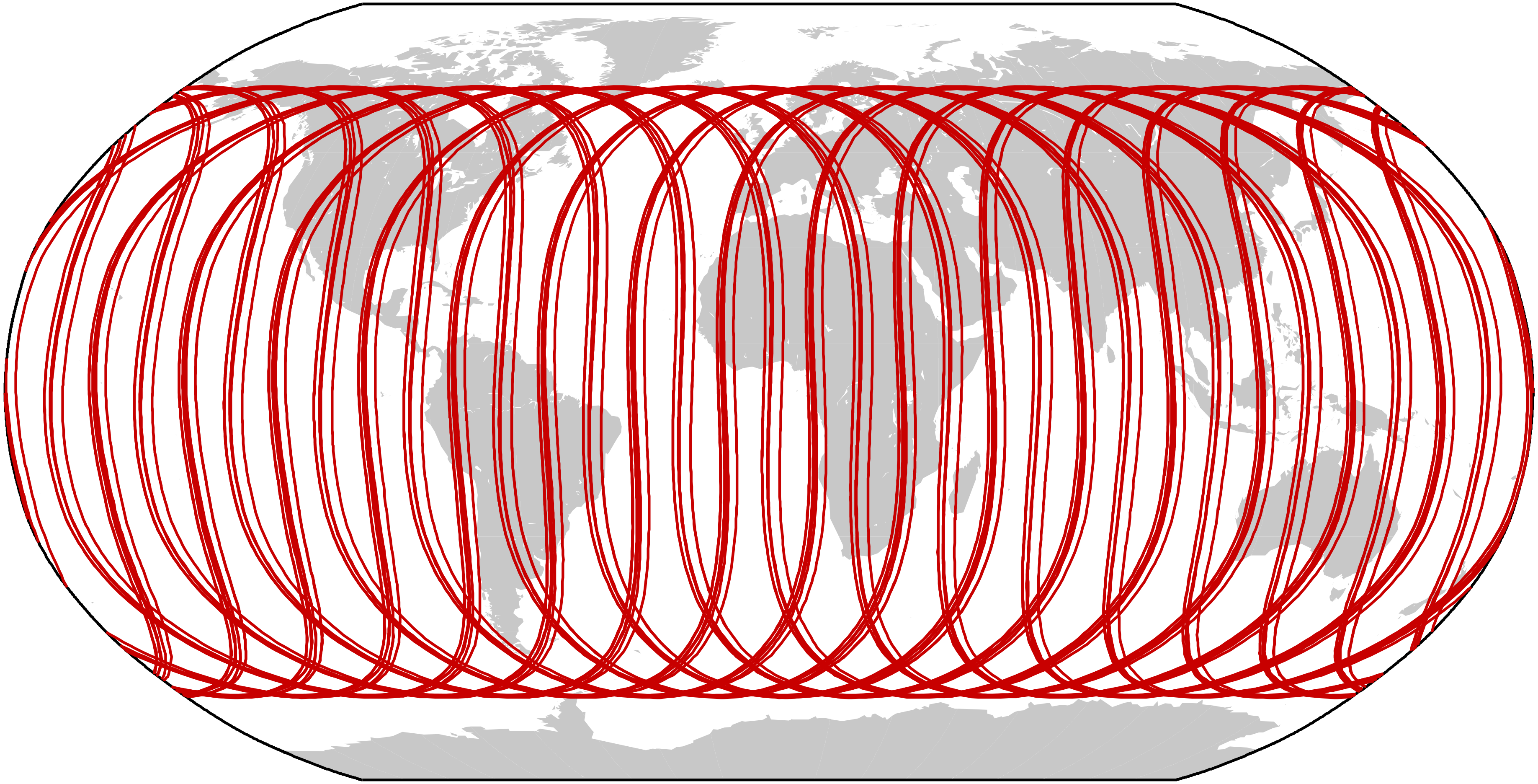


day of year 2008:060 to 069

# GPS/GLONASS Orbit Characteristics

Ground track for the GLONASS constellation

Ground track for R01 to R08 for ten days

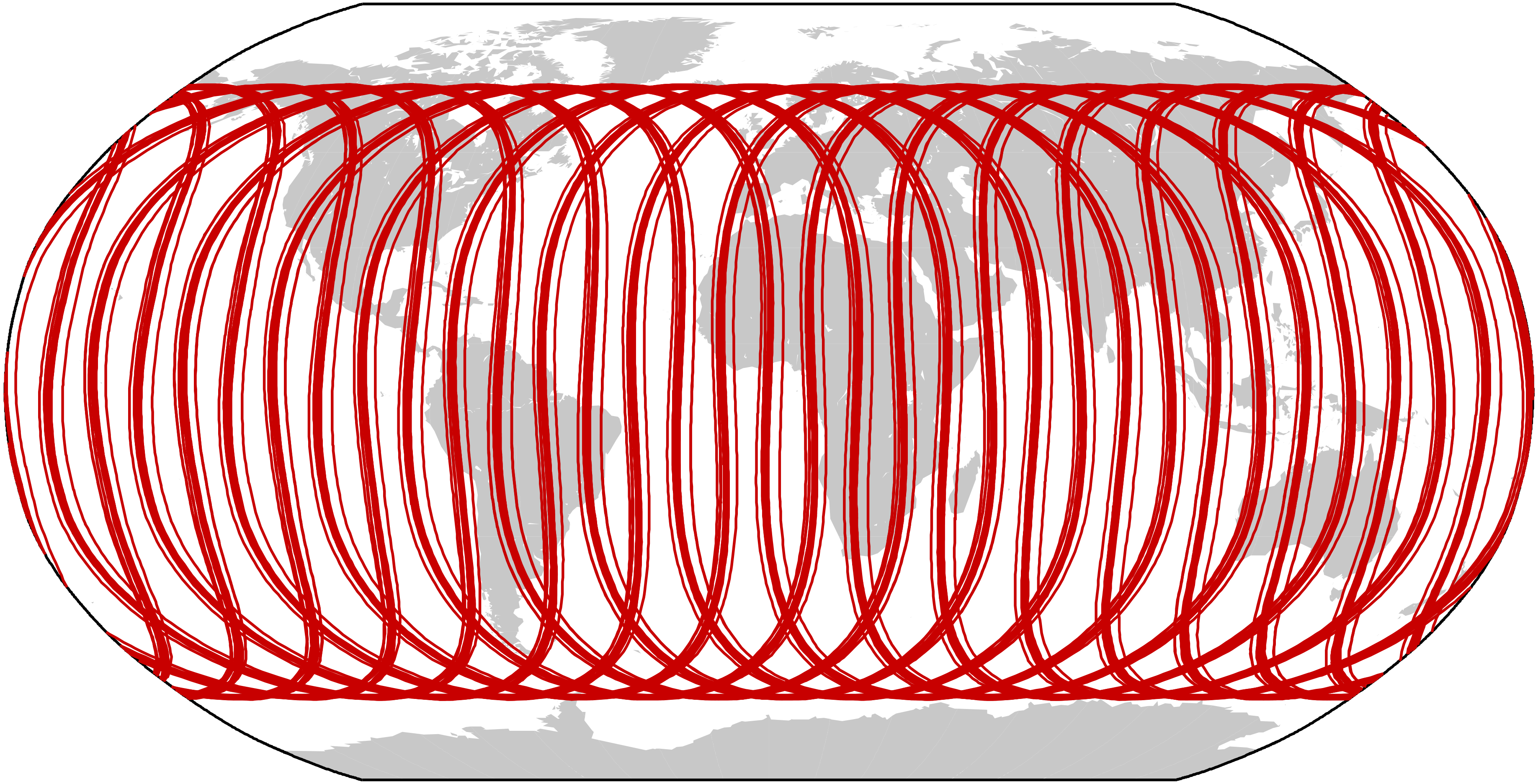


day of year 2008:060 to 069

# GPS/GLONASS Orbit Characteristics

Ground track for the GLONASS constellation

Ground track for all satellites for ten days

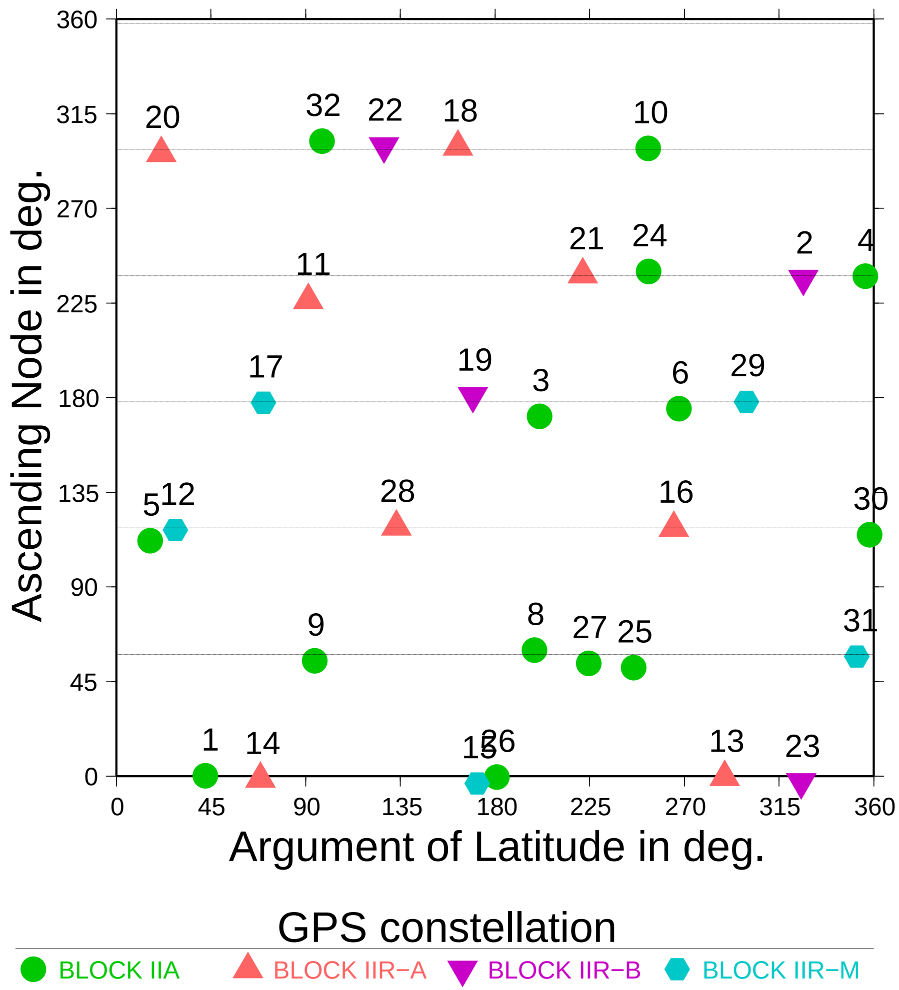


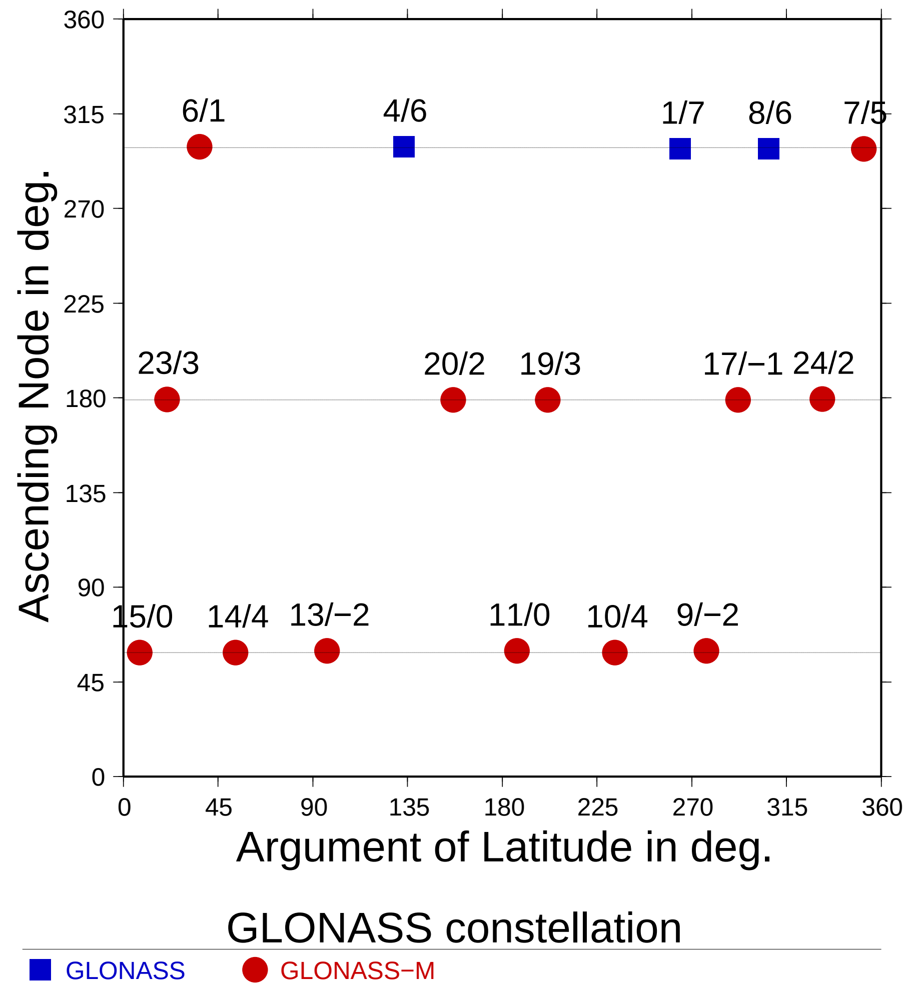
day of year 2008:060 to 069

# GPS/GLONASS Orbit Characteristics

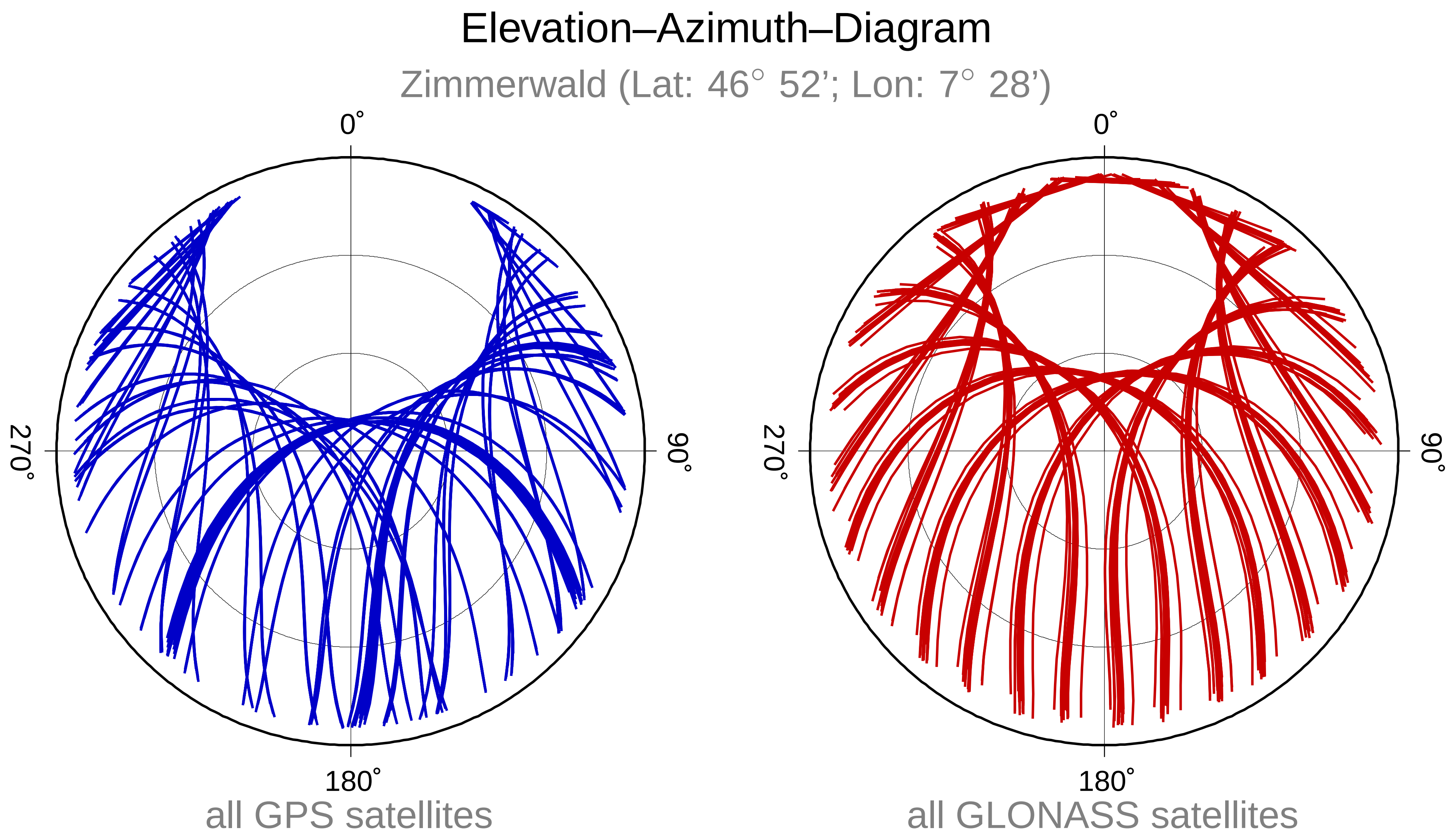
## Constellation Status

day of year 2008:060



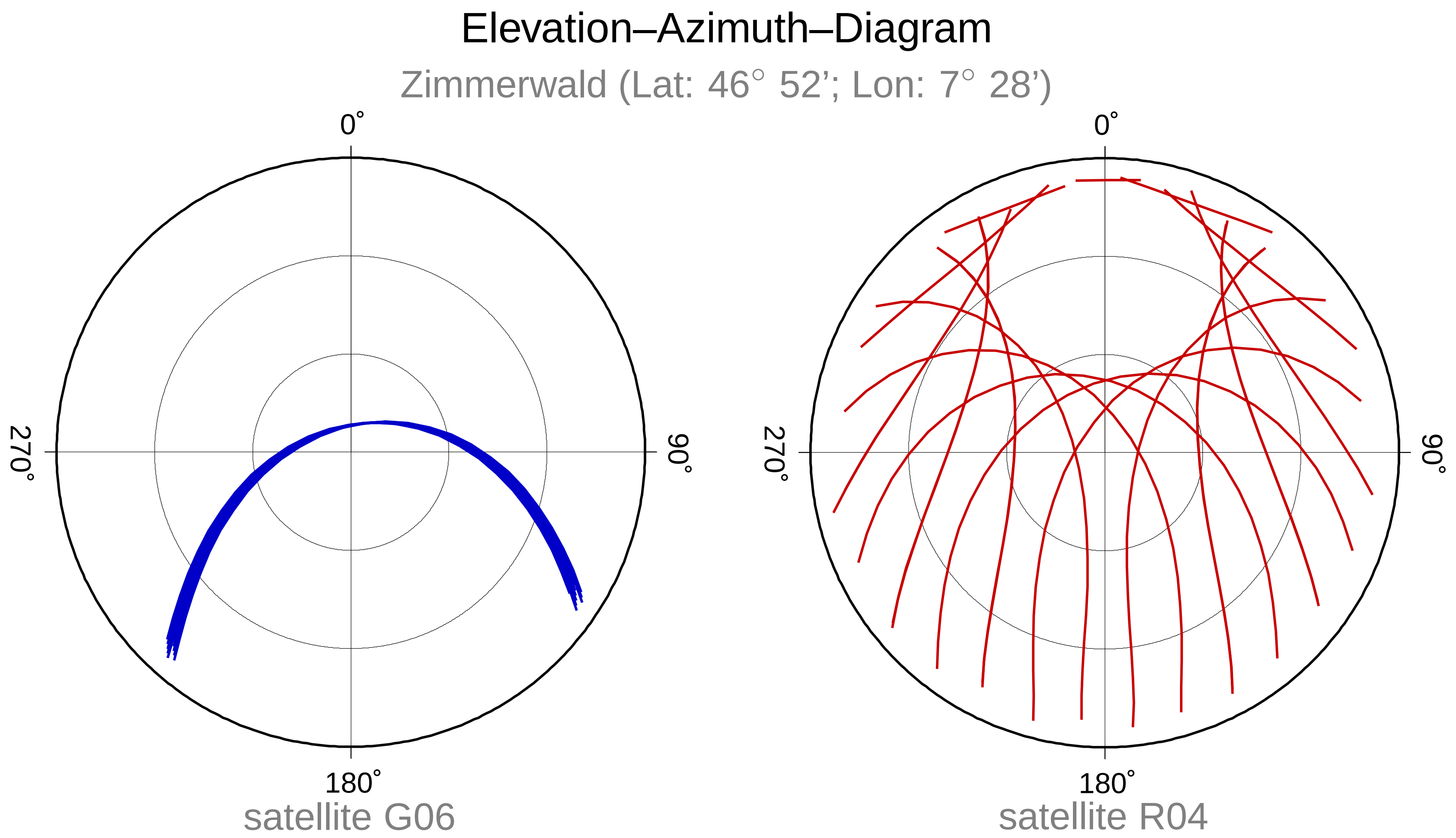



# GPS/GLONASS Orbit Characteristics



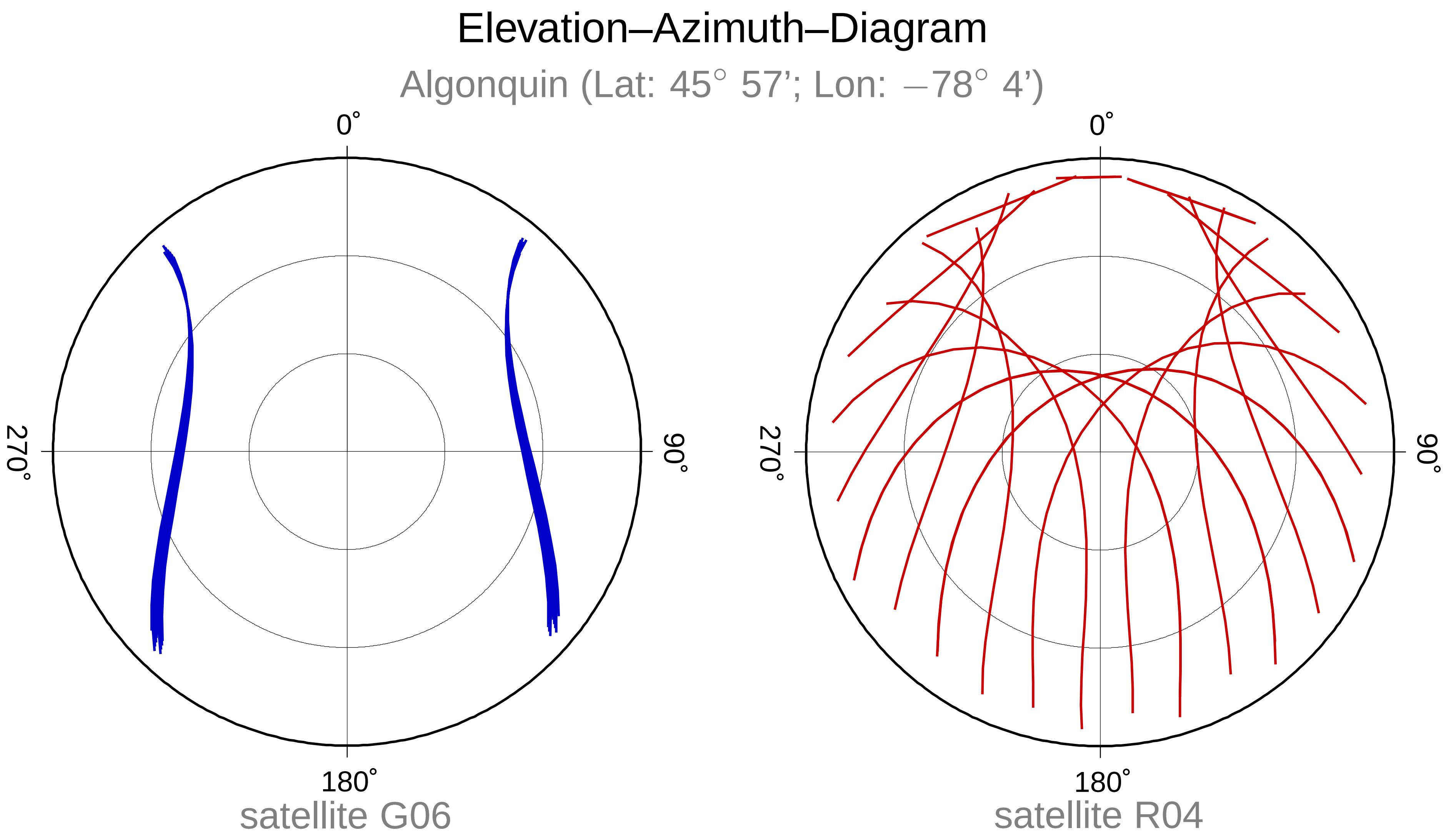

day of year 2008:060 to 069

# GPS/GLONASS Orbit Characteristics




day of year 2008:060 to 069

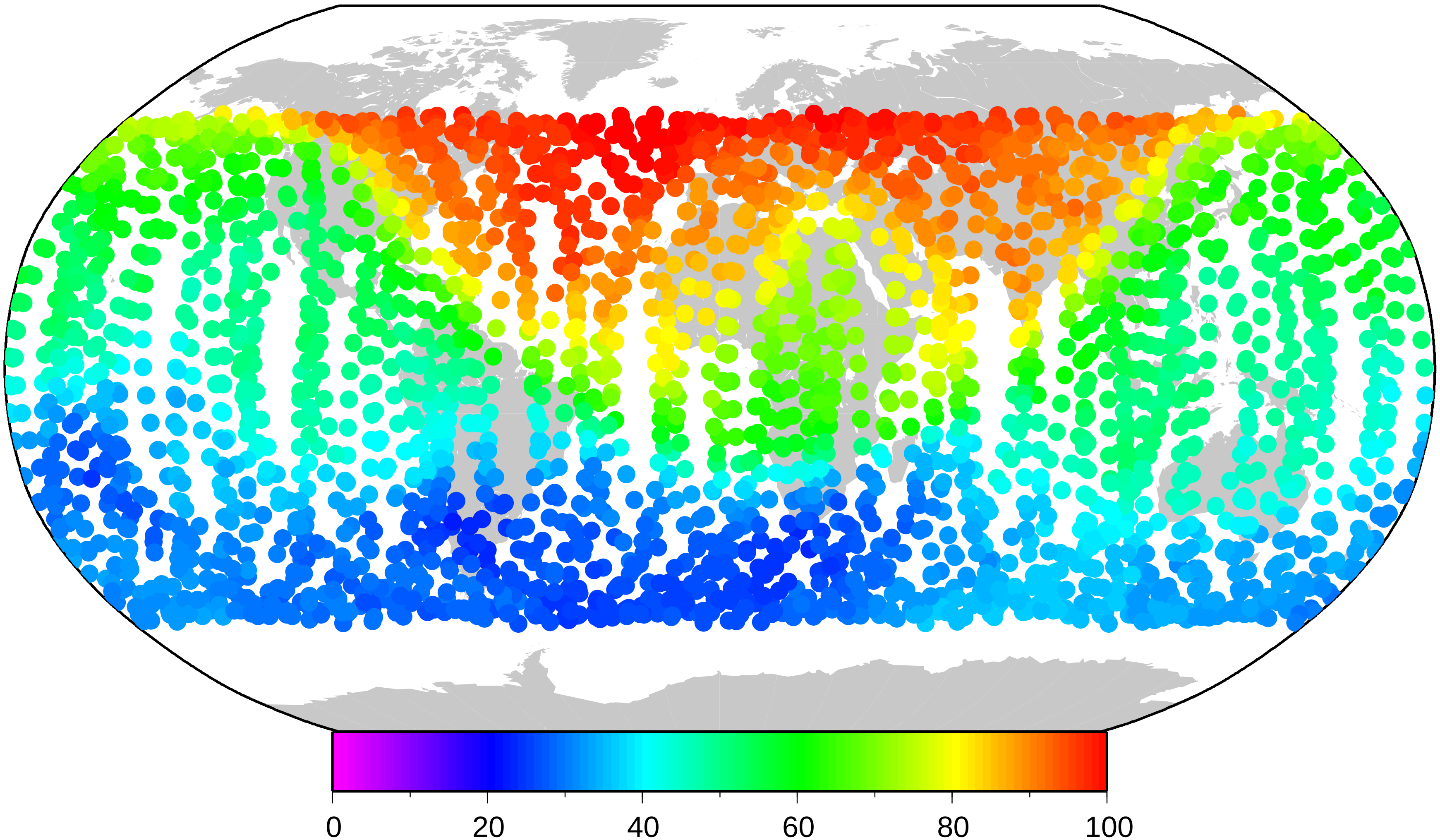
# GPS/GLONASS Orbit Characteristics




day of year 2008:060 to 069

# GPS/GLONASS Orbit Characteristics

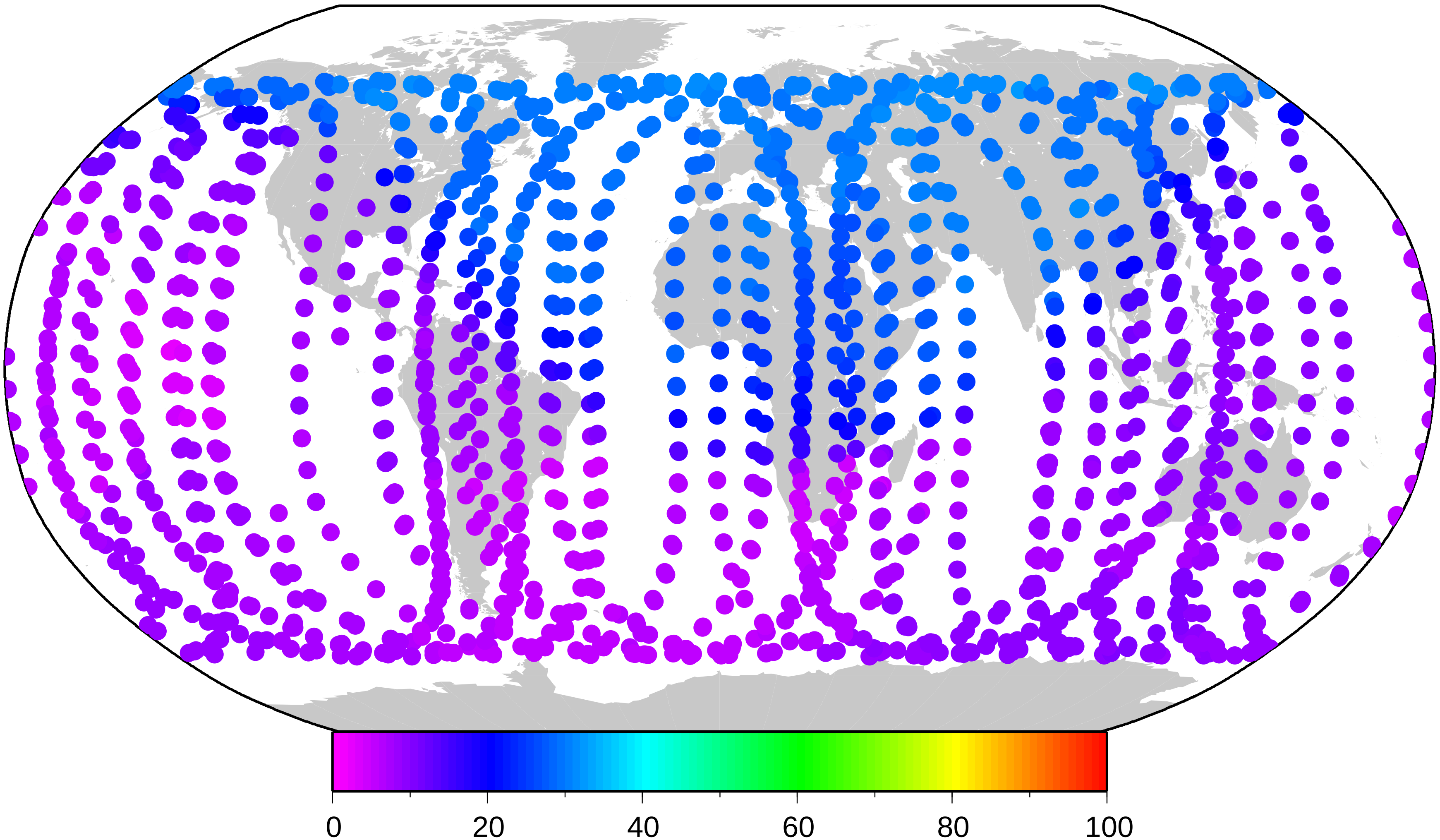
Number of stations tracking a GPS satellite




Assuming the CODE final network with 5° cut–off and 15 minutes sampling, day of year 2008:060

# GPS/GLONASS Orbit Characteristics

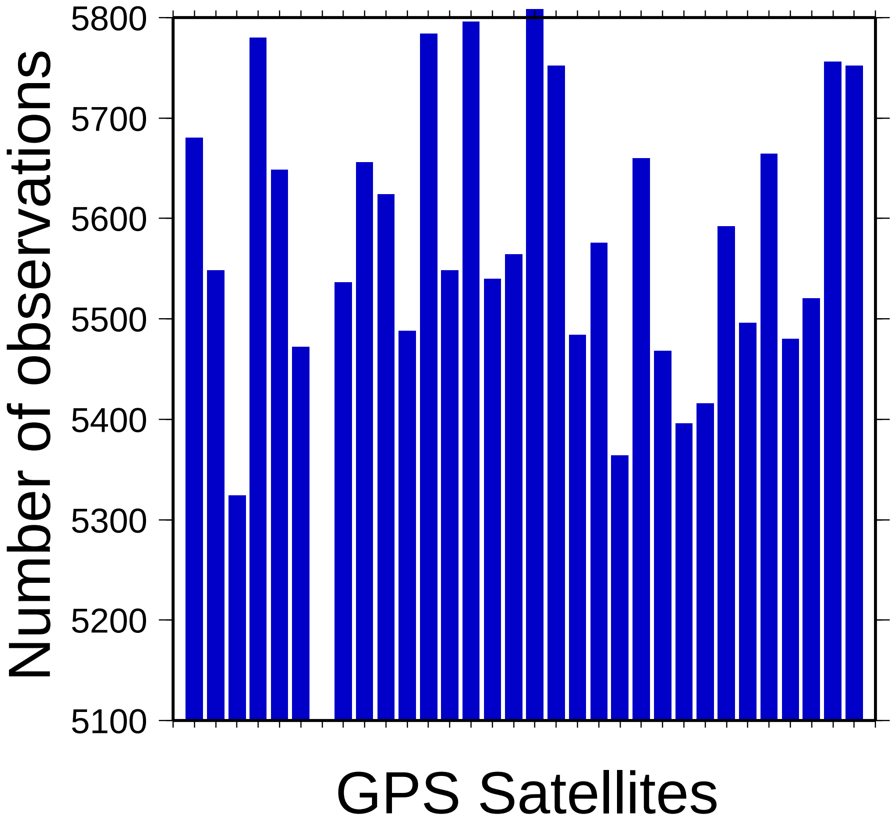
Number of stations tracking a GLONASS satellite

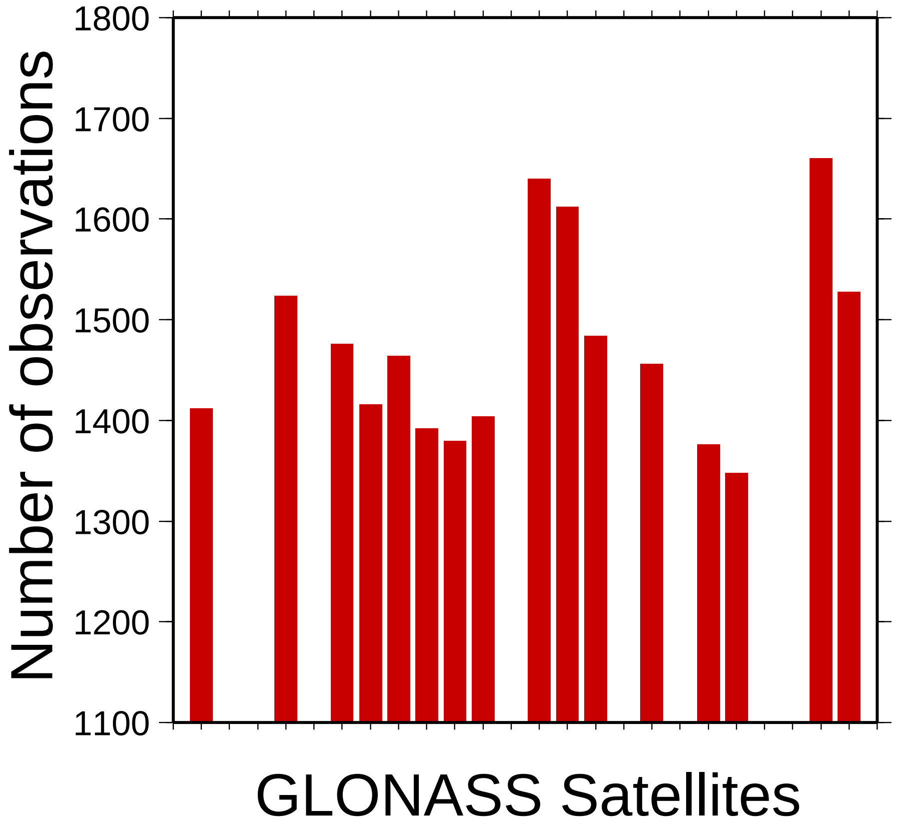



Assuming the CODE final network with 5° cut–off and 15 minutes sampling, day of year 2008:060

# GPS/GLONASS Orbit Characteristics

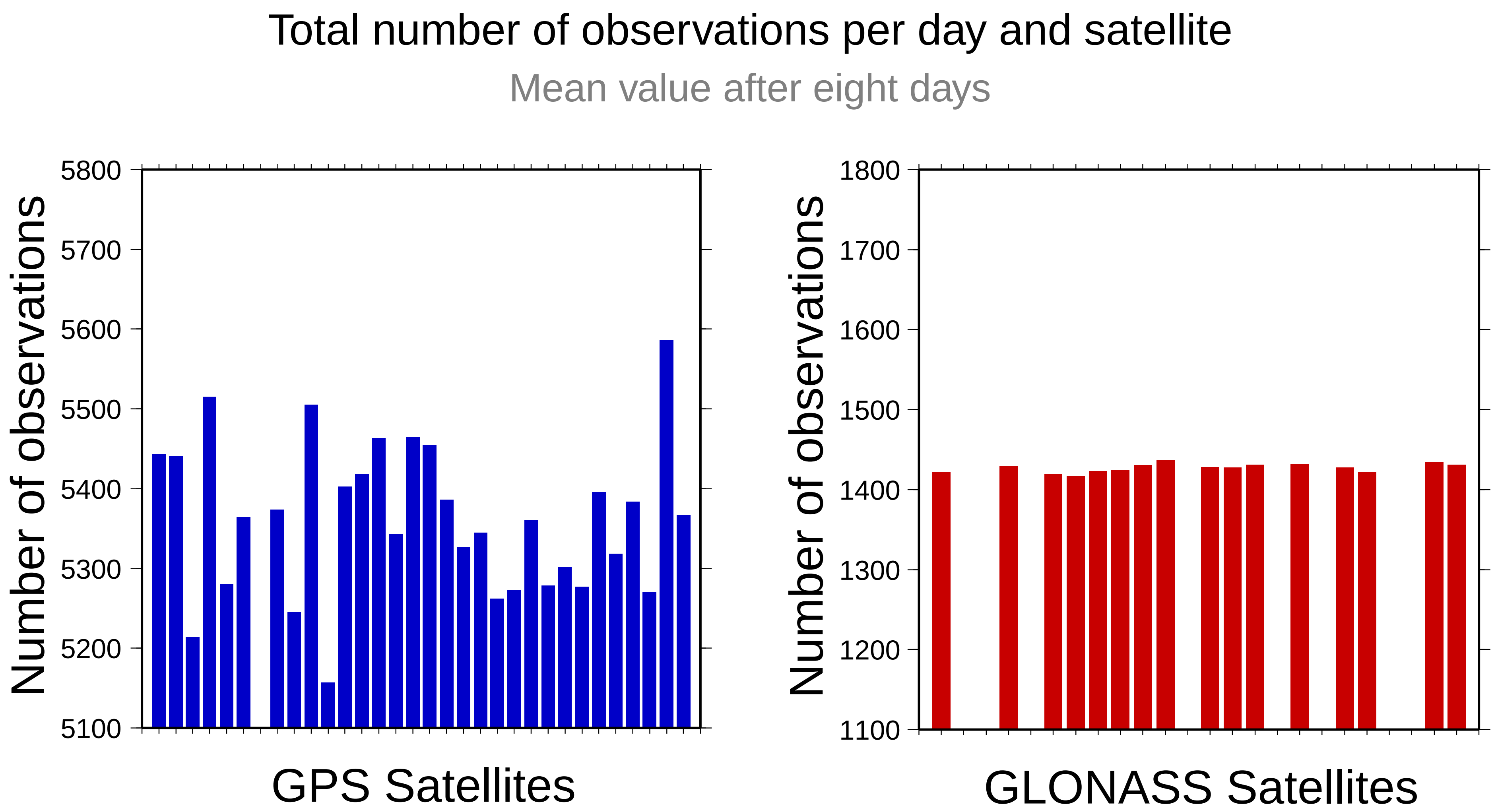
Total number of observations per day and satellite




Assuming the CODE final network with 5° cut–off and 15 minutes sampling, day of year 2008:060

# GPS/GLONASS Orbit Characteristics

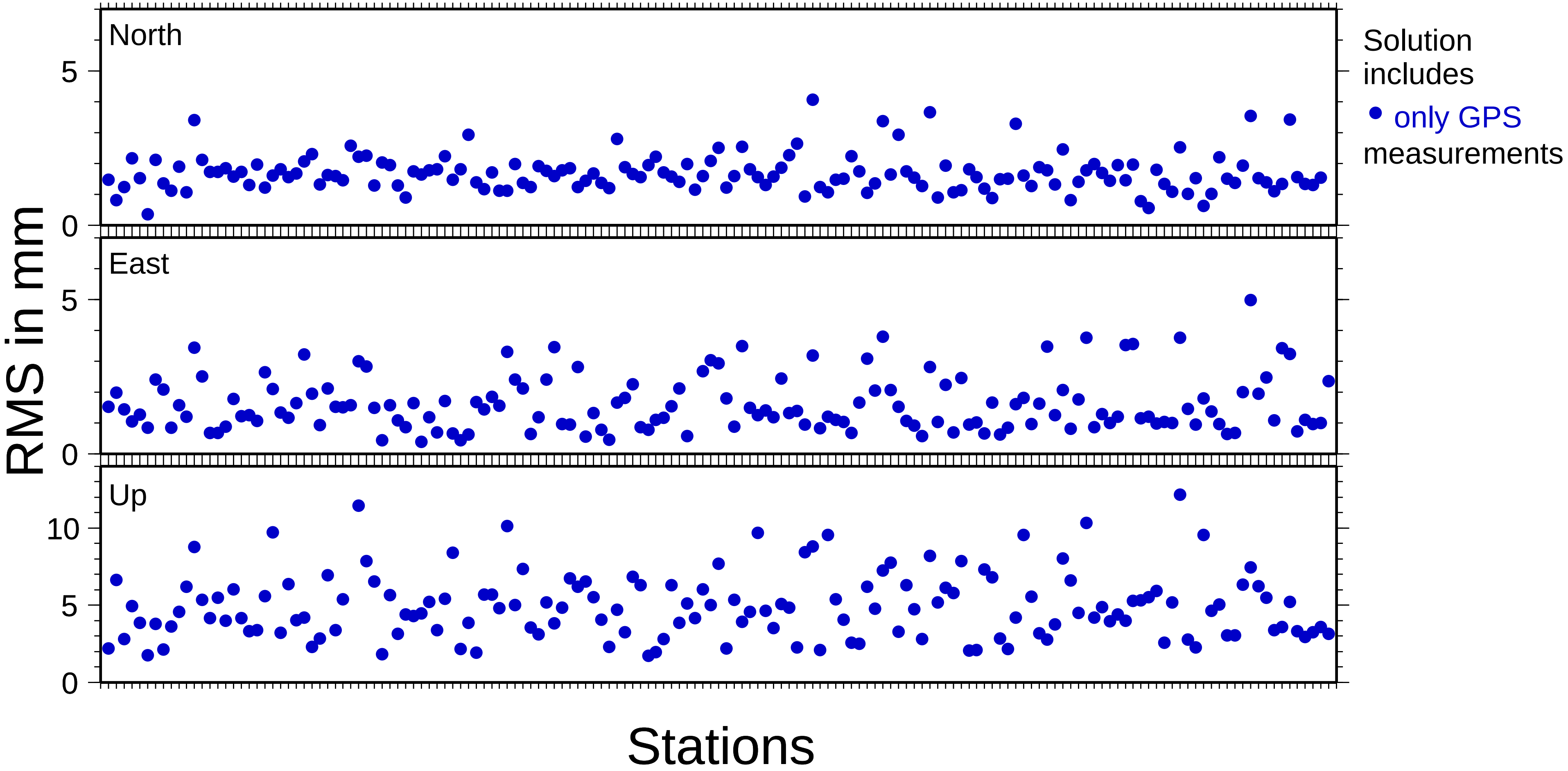



Assuming the CODE final network with 5° cut–off and 15 minutes sampling, day of year 2008:060 to 067

# Comparisons of Global Solutions

Repeatability of daily station coordinate solutions

RMS of 8 daily coordinate solutions




CODE final solution for day of year 2007:060 to 067

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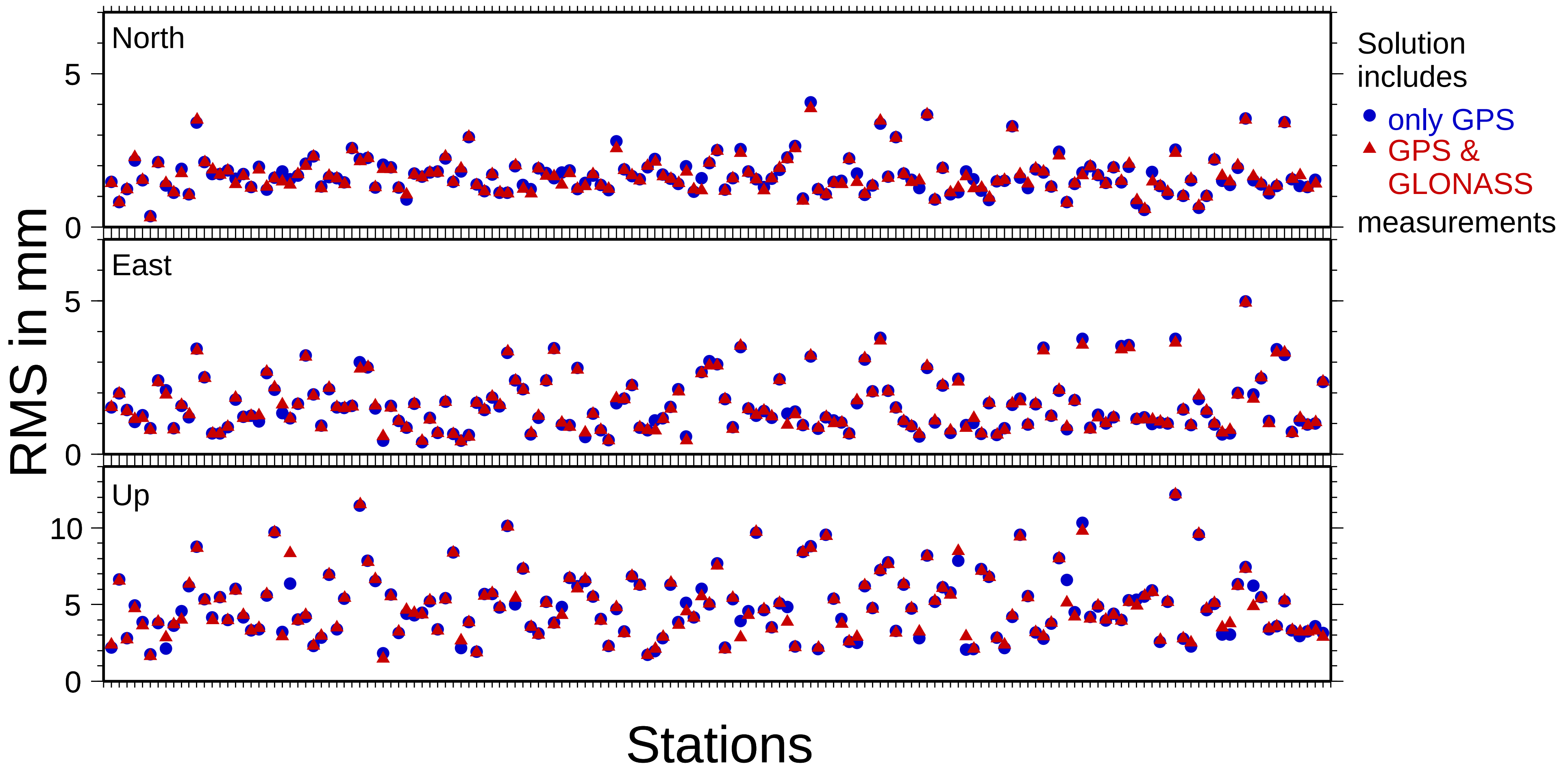


CODE final solution for day of year 2007:060 to 067

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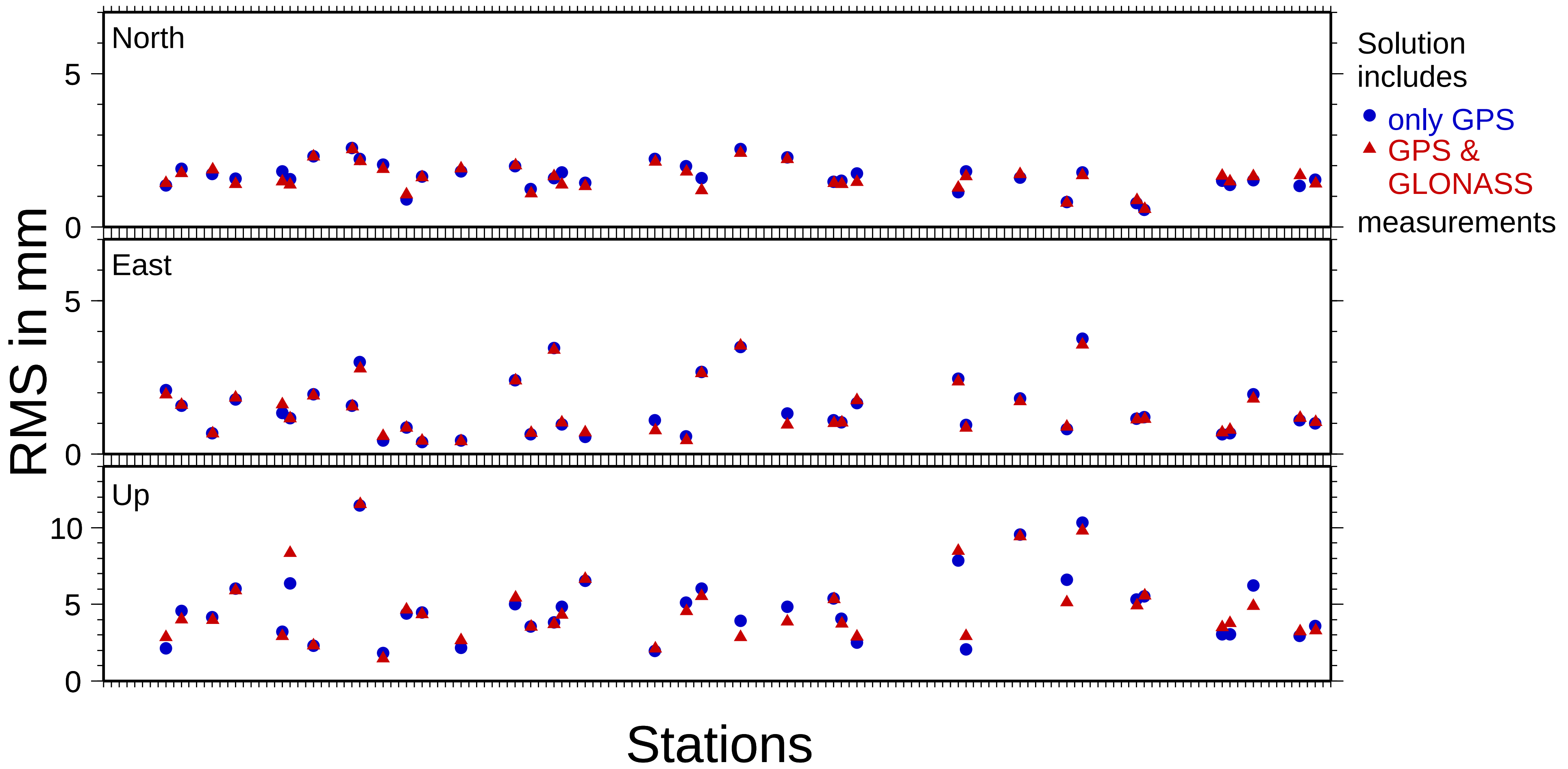
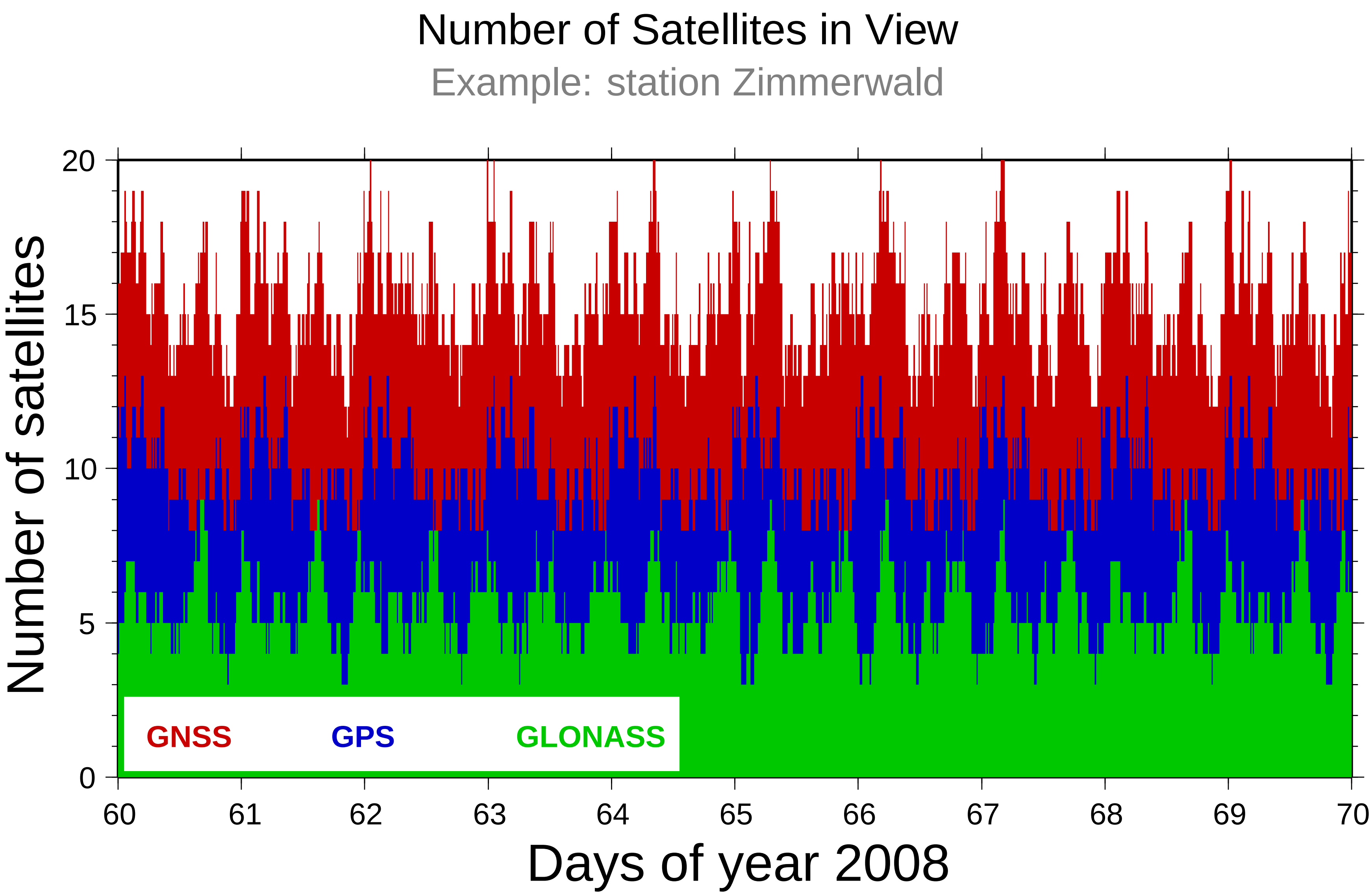



CODE final solution for day of year 2007:060 to 067

# PDOP: Constellation Effects

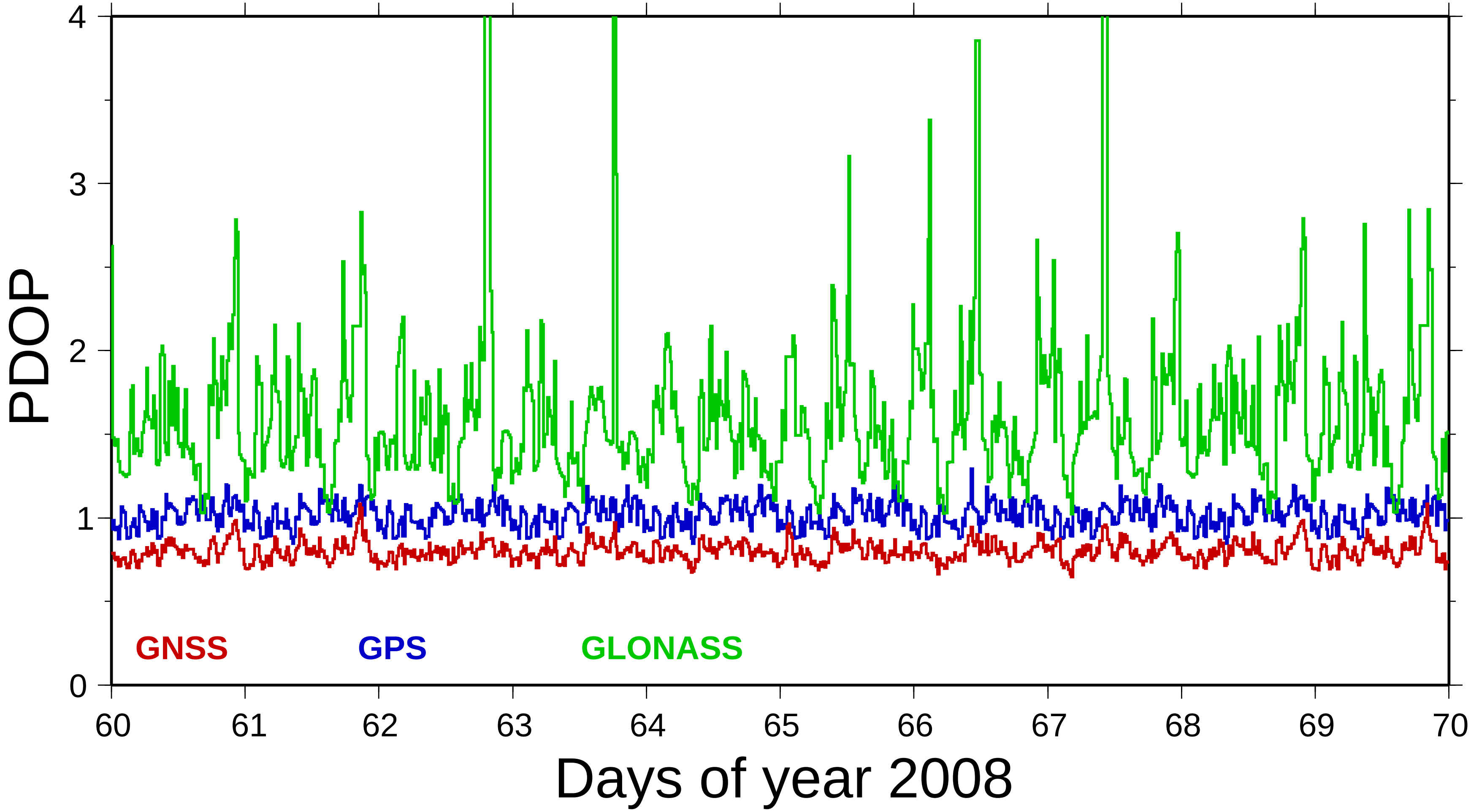



elevation cut–off 5°, day of year 2008:060 to 069

# PDOP: Constellation Effects

PDOP values for satellite constellation in view

Example: station Zimmerwald




elevation cut–off 5°, day of year 2008:060 to 069

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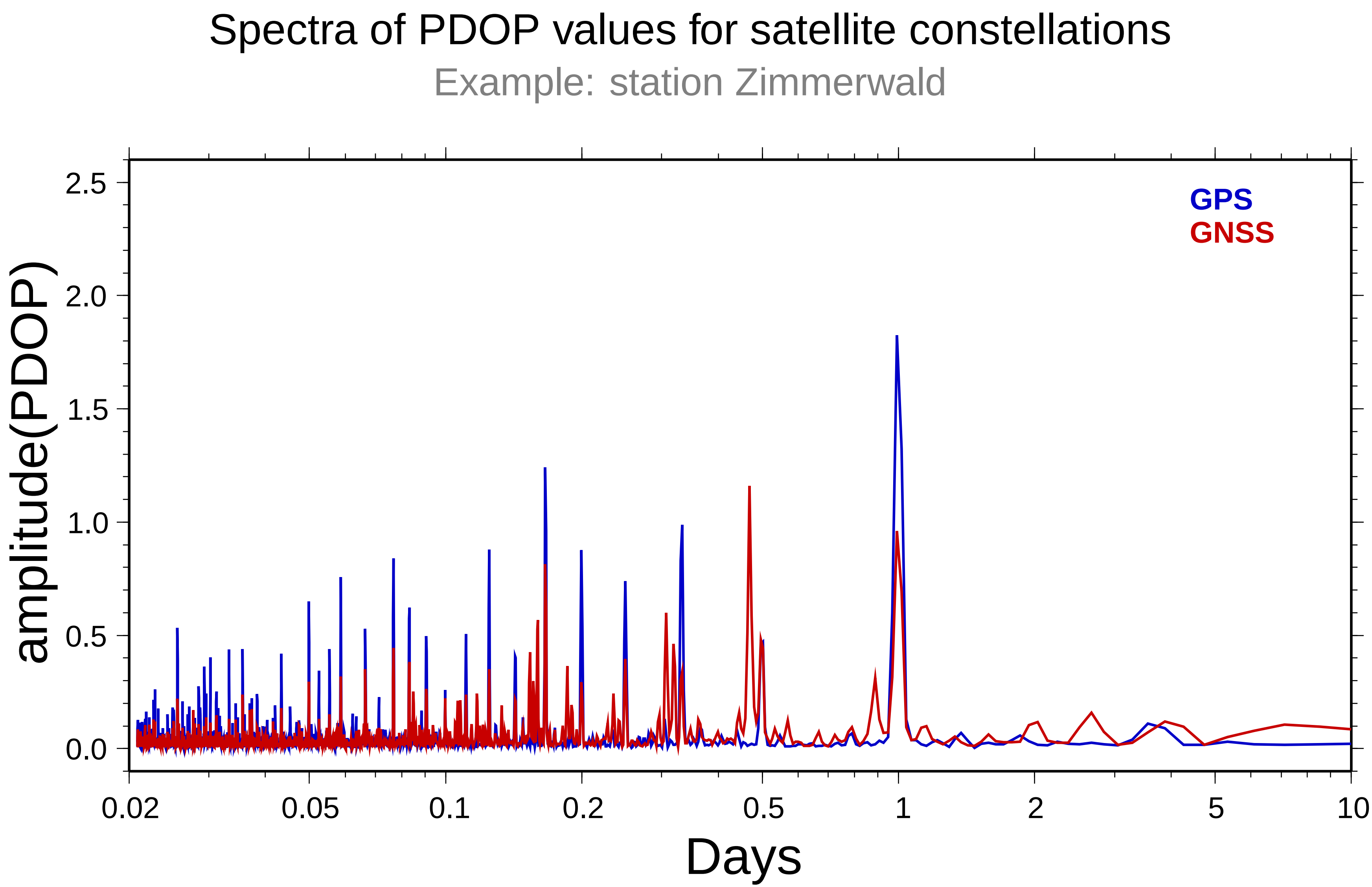
# PDOP: Constellation Effects

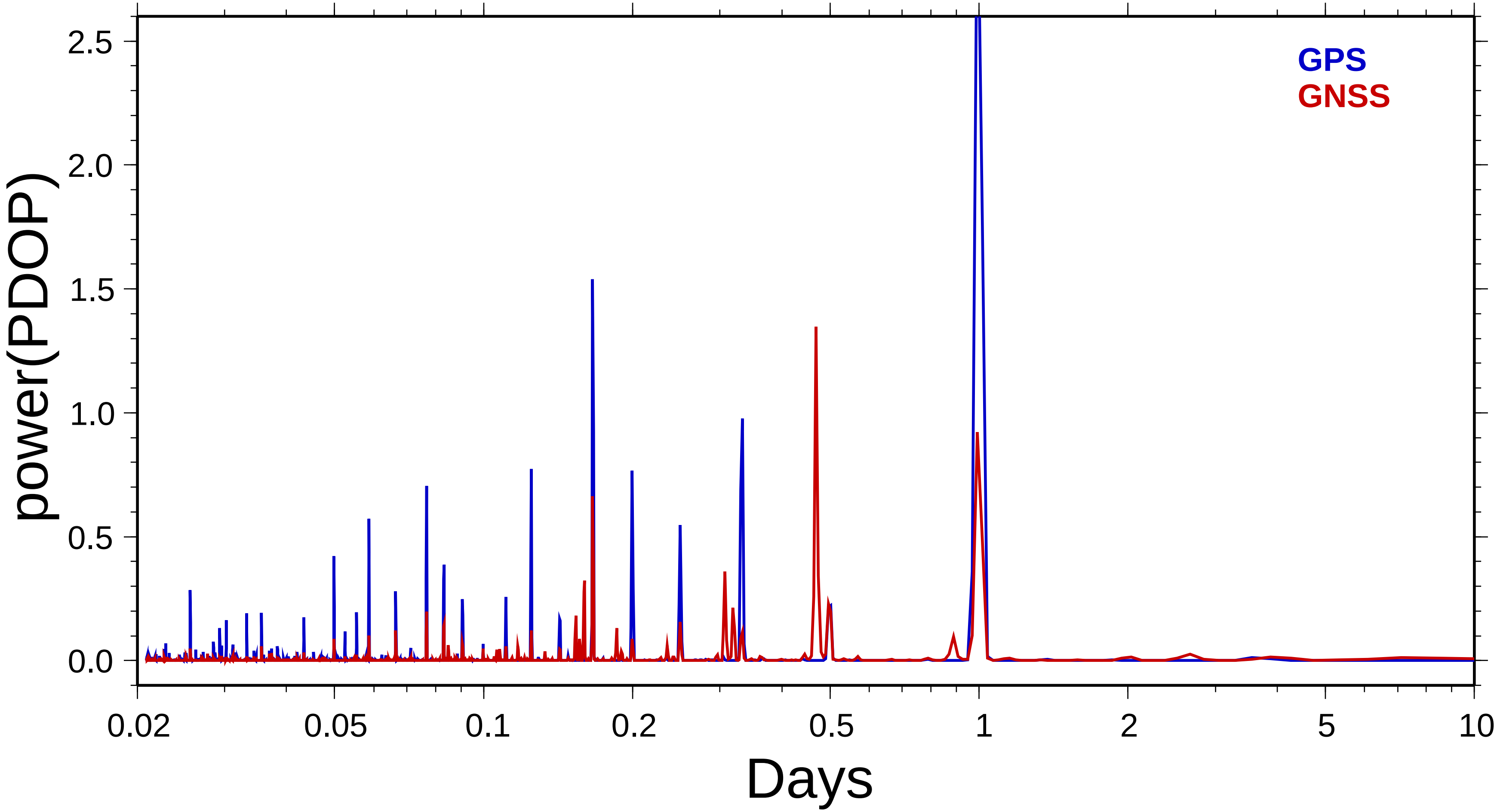



elevation cut–off 5°, day of year 2008:020 to 069

# PDOP: Constellation Effects

Spectra of PDOP values for satellite constellations

Example: station Zimmerwald




elevation cut–off 5°, day of year 2008:020 to 069

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Spectra of PDOP values for satellite constellations

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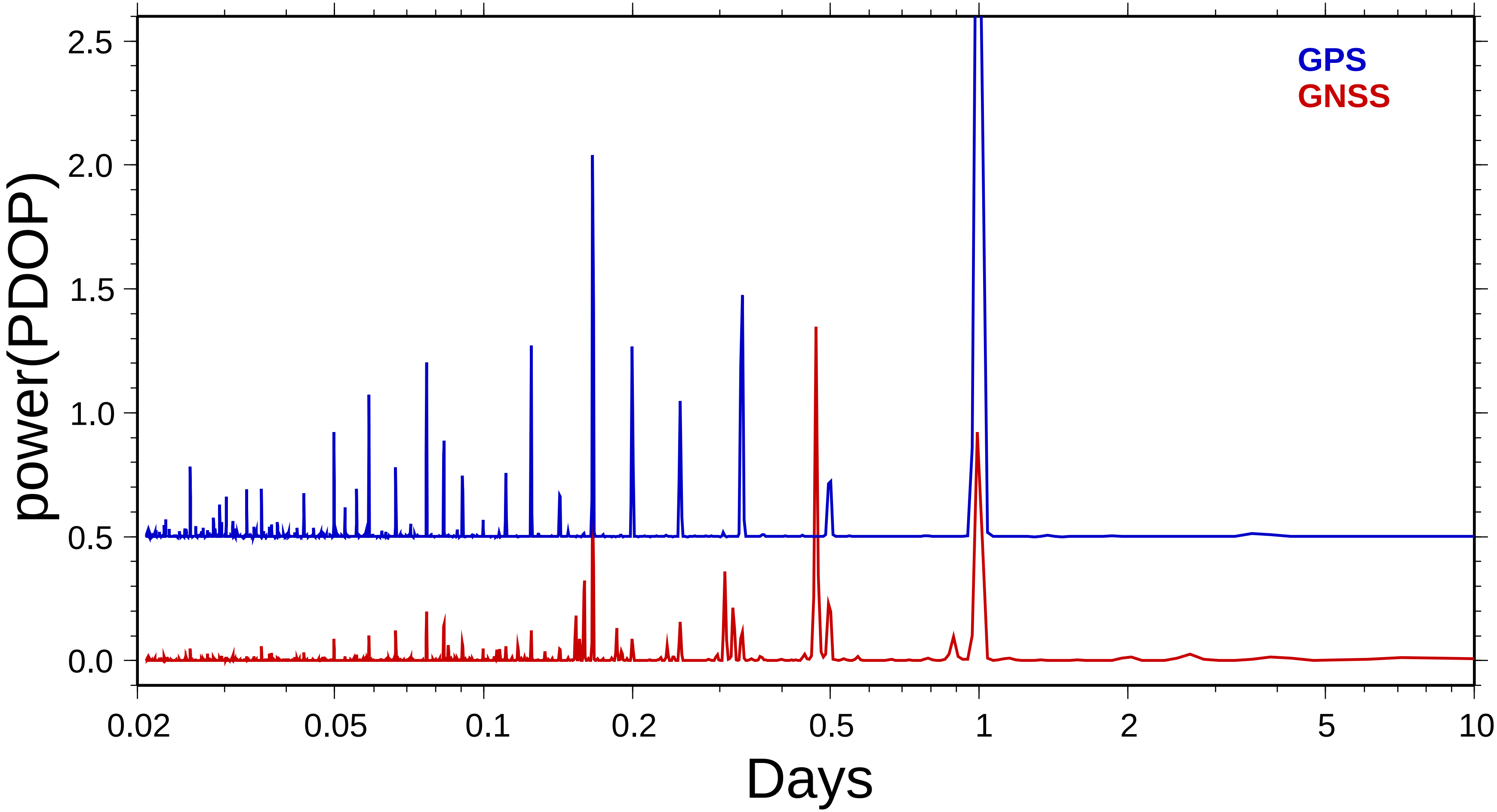


elevation cut–off 5°, day of year 2008:020 to 069

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Spectra of PDOP values for satellite constellations

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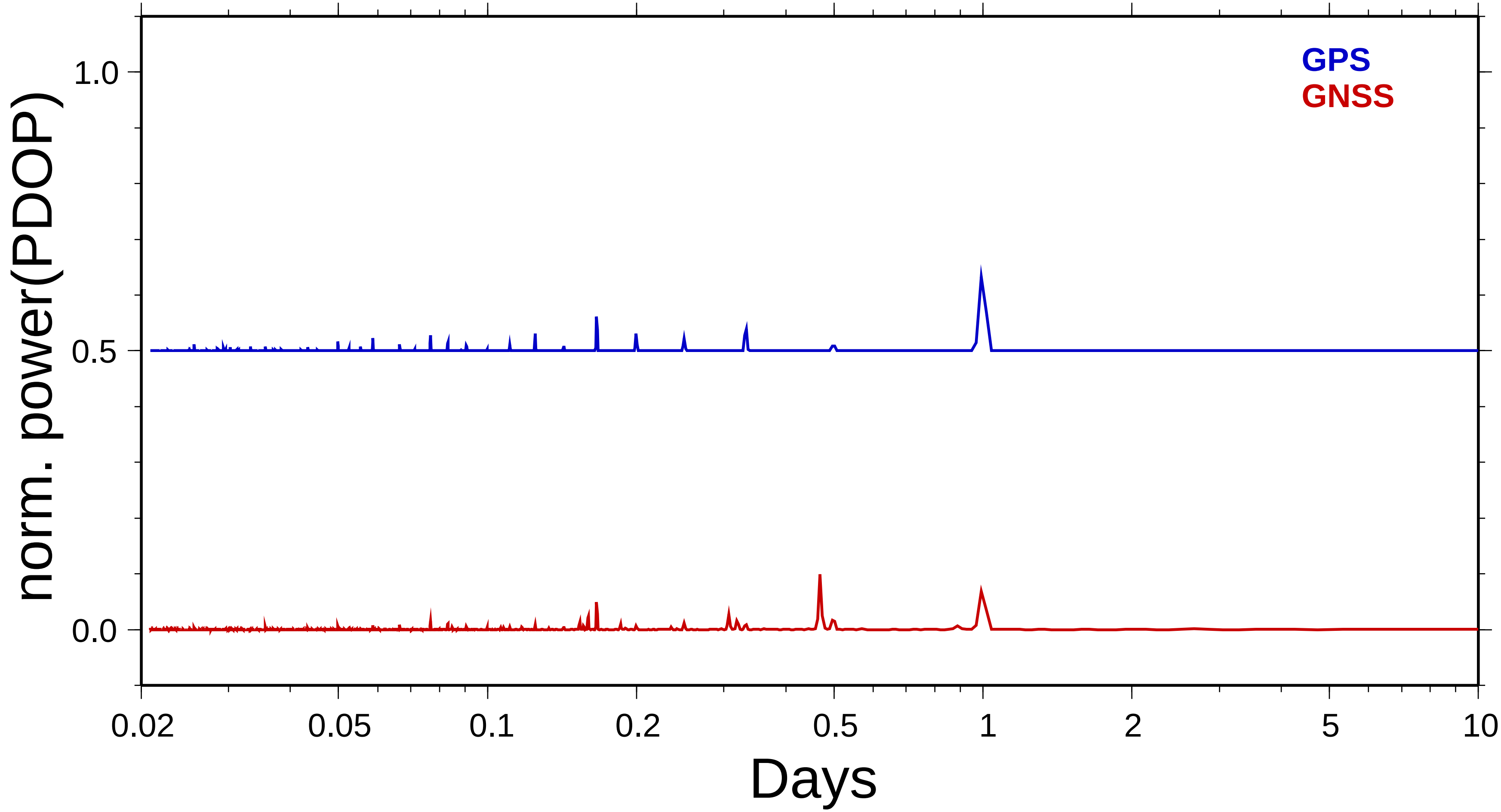
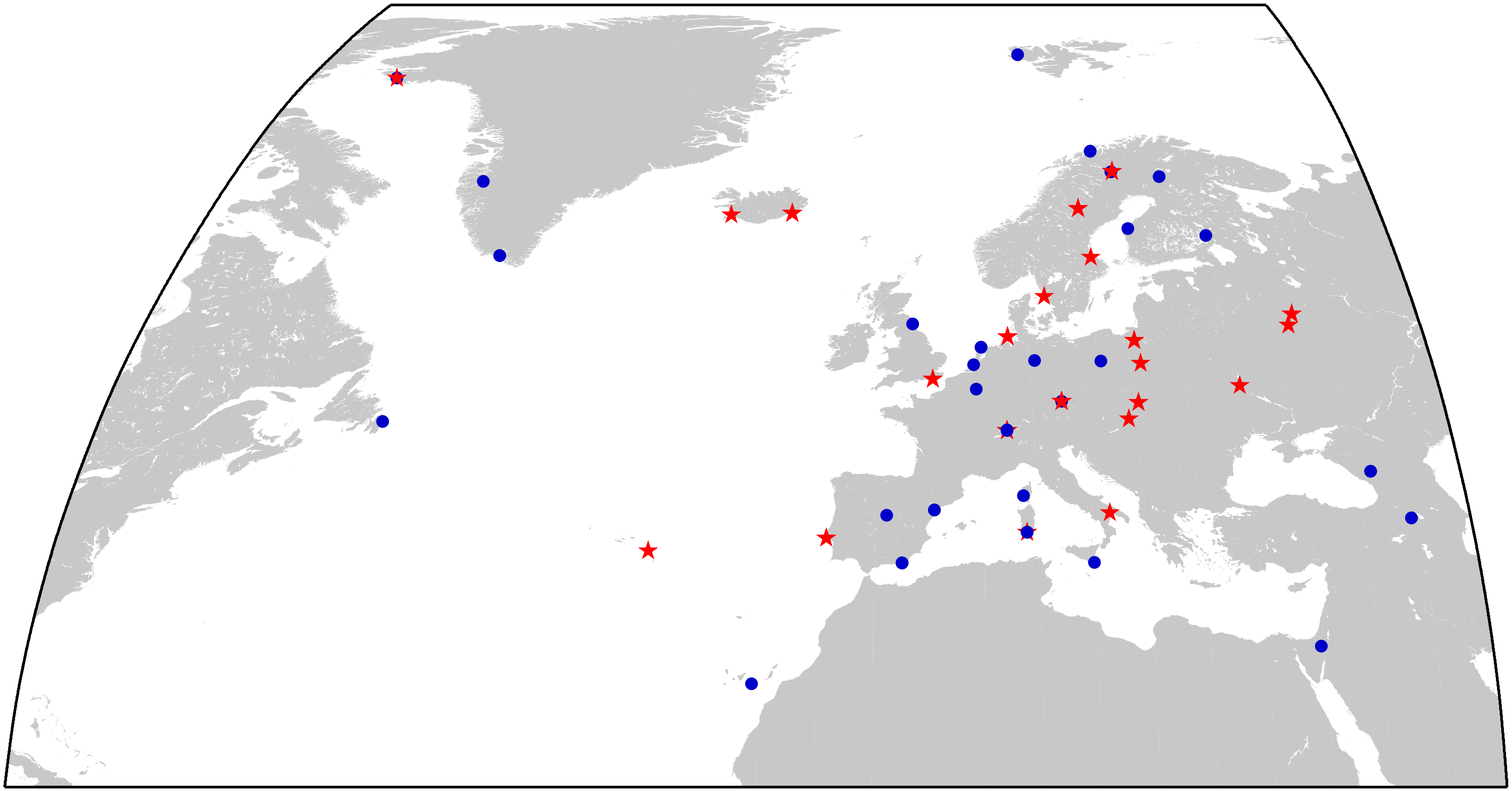



elevation cut–off 5°, day of year 2008:020 to 069

CODE EPN network



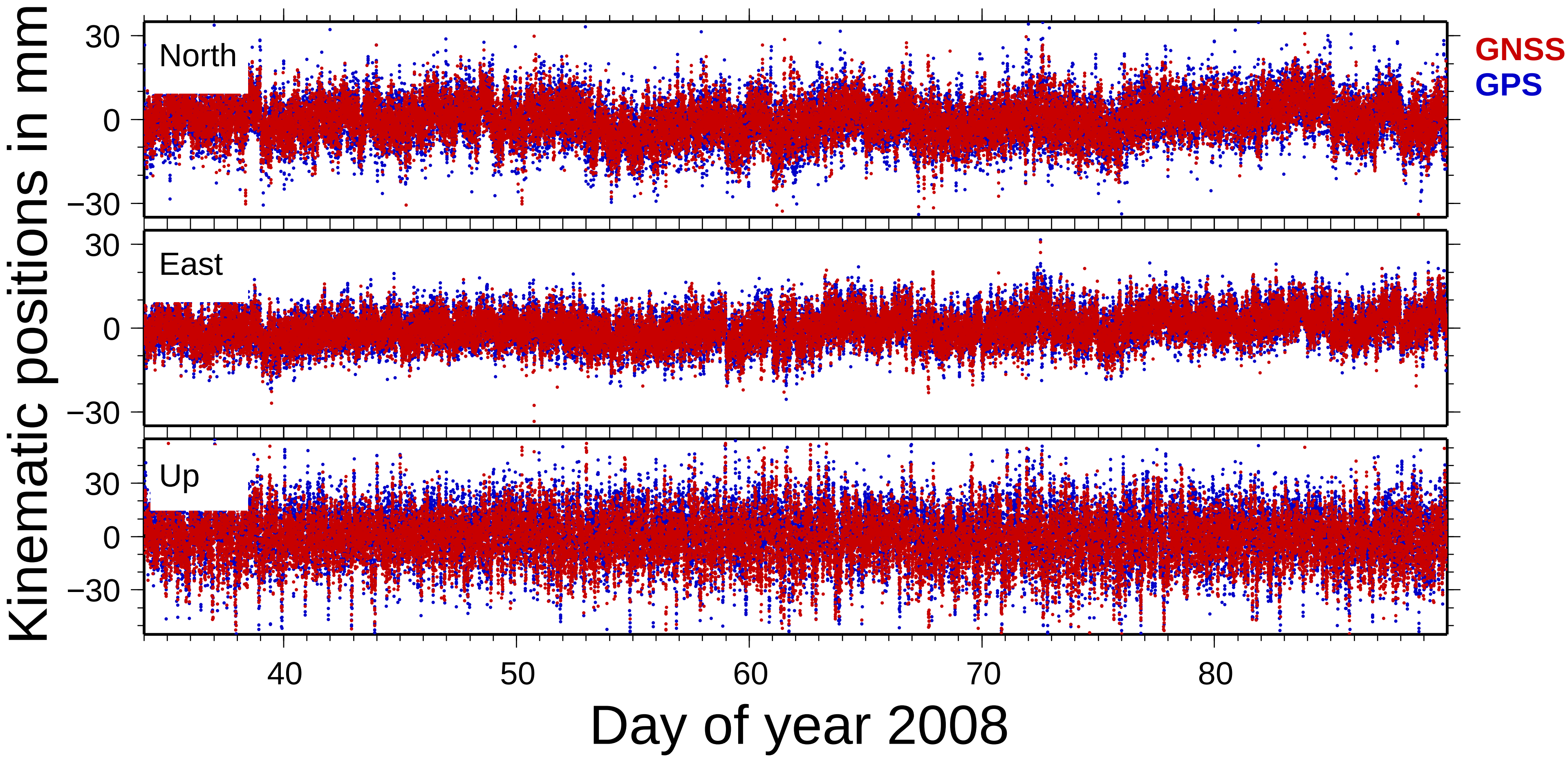
Receivers tracking: ★ GPS/GLONASS (24) ● only GPS (29)

CODE EPN solution for day of year 2007:034 to 089

# Performance of a Kinematic Positioning

Results from a kinematic positioning

Example: station Zimmerwald (ZIM2)



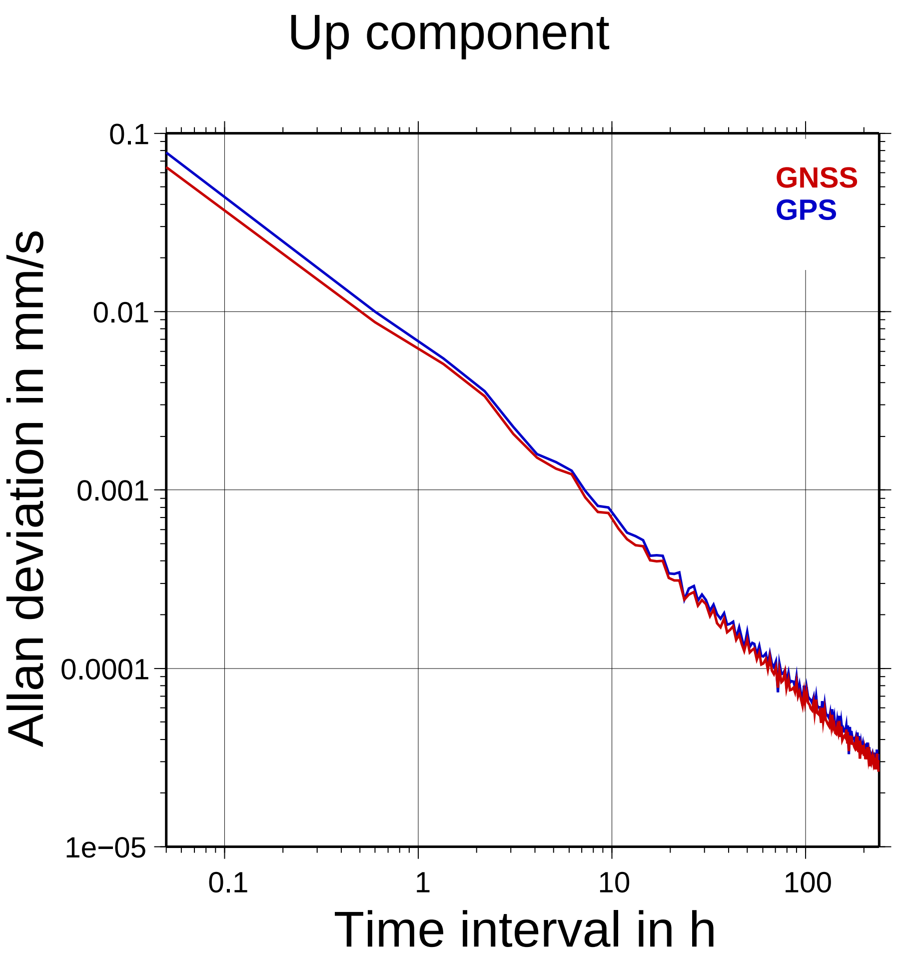

CODE EPN solution for day of year 2007:034 to 089

# Performance of a Kinematic Positioning

Allan deviation from a kinematic positioning

Example: station Zimmerwald (ZIM2)

- The Allan deviation reflects the noise behavior of a time series.
- It is comparable with the RMS of epoch differences.
- The time interval gives the length between these epochs.



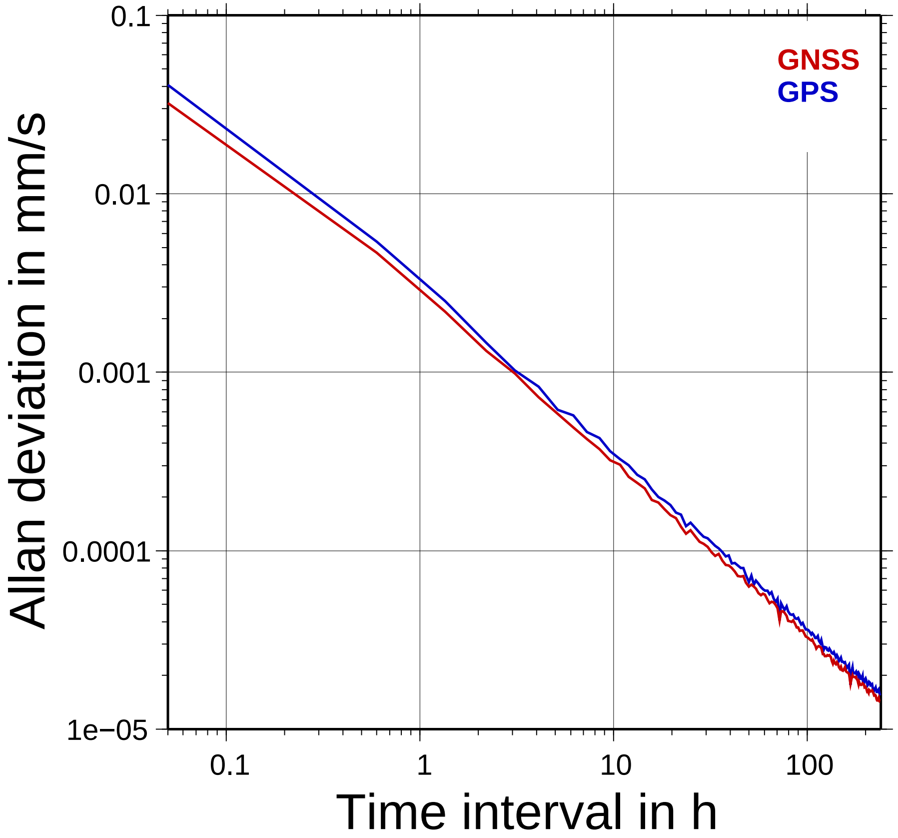

CODE EPN solution for day of year 2007:034 to 089

# Performance of a Kinematic Positioning

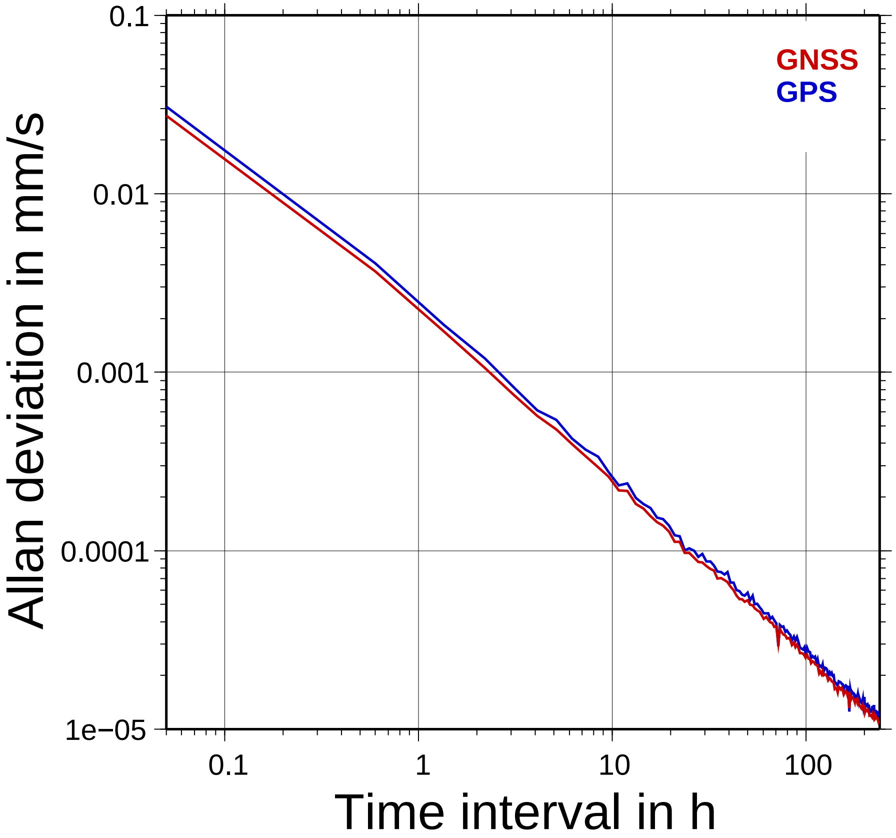
Allan deviation from a kinematic positioning

Example: station Zimmerwald (ZIM2)

North component




East component




CODE EPN solution for day of year 2007:034 to 089

# Summary and Conclusions

**What did we learn from studying the orbit geometry?**

# Summary and Conclusions

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The GPS constellation

- has a strong repetition rate of a sideral day.

The GLONASS constellation

- has a higher variability (repetition rate of 8 sideral days after 17 revolutions).

# Summary and Conclusions

## What did we learn from studying the orbit geometry?

The GPS constellation

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- is longitude dependent because each satellite follows its own ground track.

The GLONASS constellation

- has a higher variability (repetition rate of 8 sideral days after 17 revolutions).
- is independent from the longitude because of the shift in the ground track for each day.

# Summary and Conclusions

## What did we learn from studying the orbit geometry?

The GPS constellation

- has a strong repetition rate of a sideral day.
- is longitude dependent because each satellite follows its own ground track.
- has the dominating frequency at a sideral day in the spectrum of the variation of the satellite geometry.

The GLONASS constellation

- has a higher variability (repetition rate of 8 sideral days after 17 revolutions).
- is independent from the longitude because of the shift in the ground track for each day.
- has the dominating frequency at once per revolution in the spectrum of the variation of the satellite geometry (uncertainty of the orbits?).

# Summary and Conclusions

## Why to compute multi–GNSS products?

- to guarantee the best possible consistency of the orbit products from different GNSS.
- to reduce the impact of the strong GPS constellation frequency of one sideral day to the obtained products.
- to improve products with a high resolution in time ($\sqrt{n}$–law, robustness).
- to monitor and provide inter–system biases.
- to allow for independent validation using SLR even after the expected decommission of G05 and G06 .
- to be in place for including the new GNSS (Galileo, Compass?) as soon as data are available.

# Summary and Conclusions

## Combination with other space–geodetic techniques is necessary also for multi–GNSS solutions

| Parameters acessable with | GNSS | VLBI | SLR |
|---|---|---|---|
| Initiale Reference Frame (ICRF),<br>(Position of Quasars) | | X | |
| Nutation | (X) | X | |
| Polar motion | X | X | X |
| UT1 | | X | |
| Length of day | (X) | | X |
| Terrestrial Reference Frame (ITRF),<br>(Position and velocities of ground stations) | X | X | X |
| Geocenter, coordinate origin | (X) | | X |