Localisation précise par moyens spatiaux

Satellite geometry in single-GNSS and multi-GNSS scenarios

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GPS/GLONASS/Galileo constellations

- Ground tracks and their repetition rates
- Observing satellites by a typical global tracking network
- Sky plots and their repetition rates
- Number of observable satellites
- PDOP and its spectra

GPS constellation

Orbital elements for GPS satellites

Semi-major axis: $a \approx 26{,}560$ km

Eccentricity: $e \approx 0$ (circular orbit)

Inclination: $i \approx 55^{o}$

Orbital planes

Number of planes: 6 plane at $\Omega_n = \Omega_0 + n \cdot 60^{o}$

Satellites per plane: 4 irregularly distributed

= 24 nominal constellation (currently 32 active)

Repetition rates

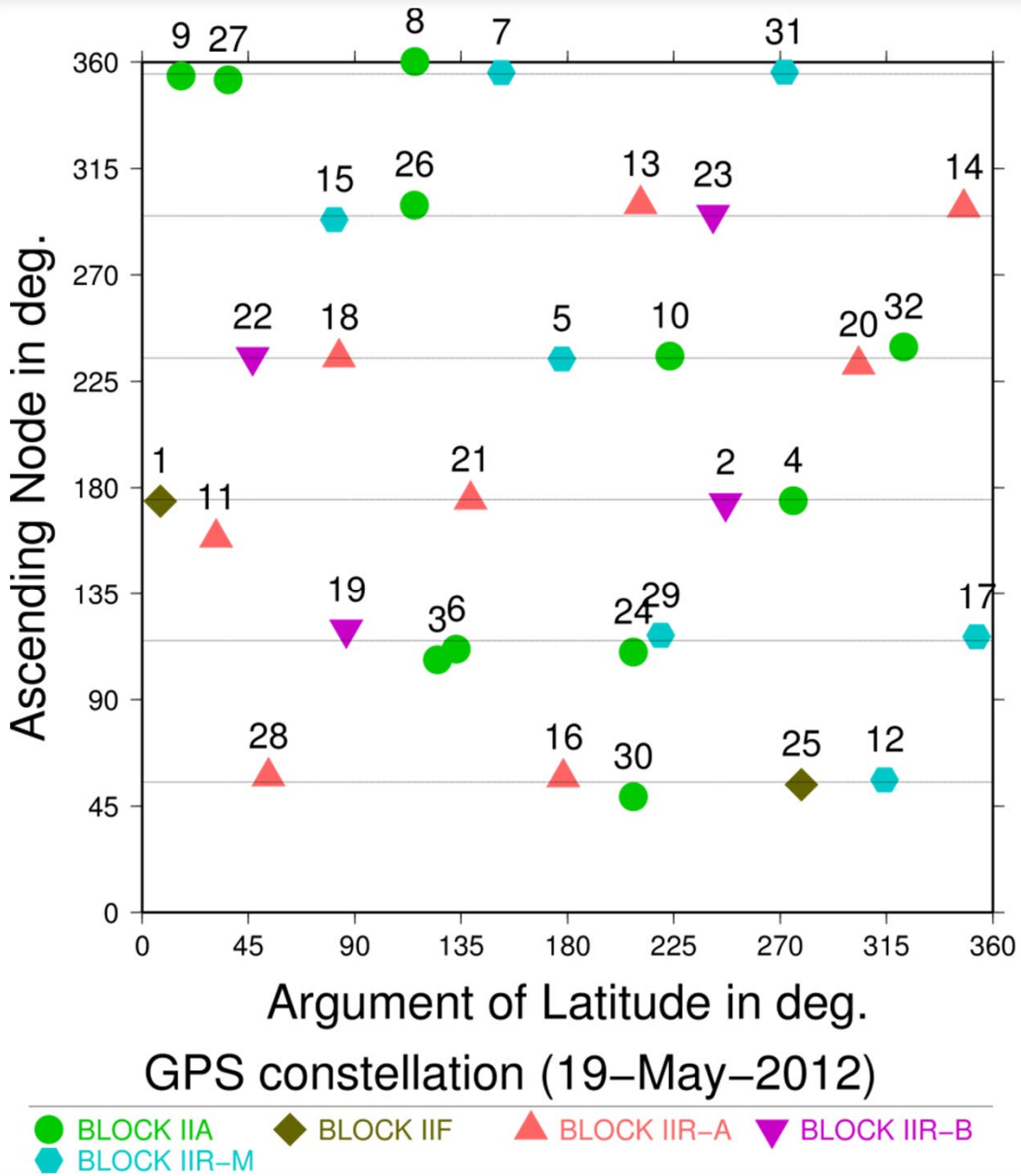
Revolution period: 11 h 58min

Repetition of the constellation: 1 sidereal day

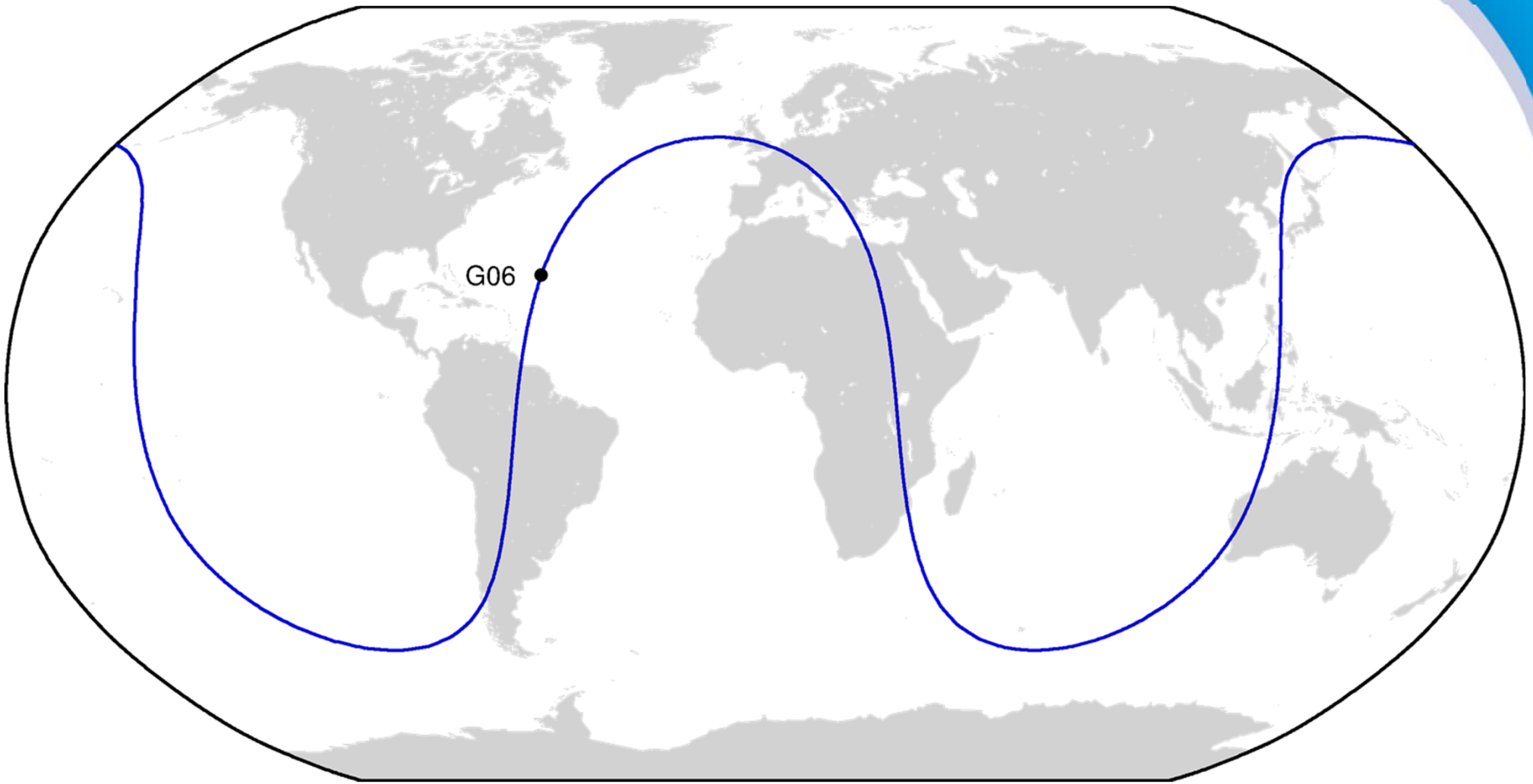
Repetition of the geometry: 23 h 56min 1 sidereal day

Repetition of the constellation means that the same satellite has to be over the same position of the Earth.

GPS constellation

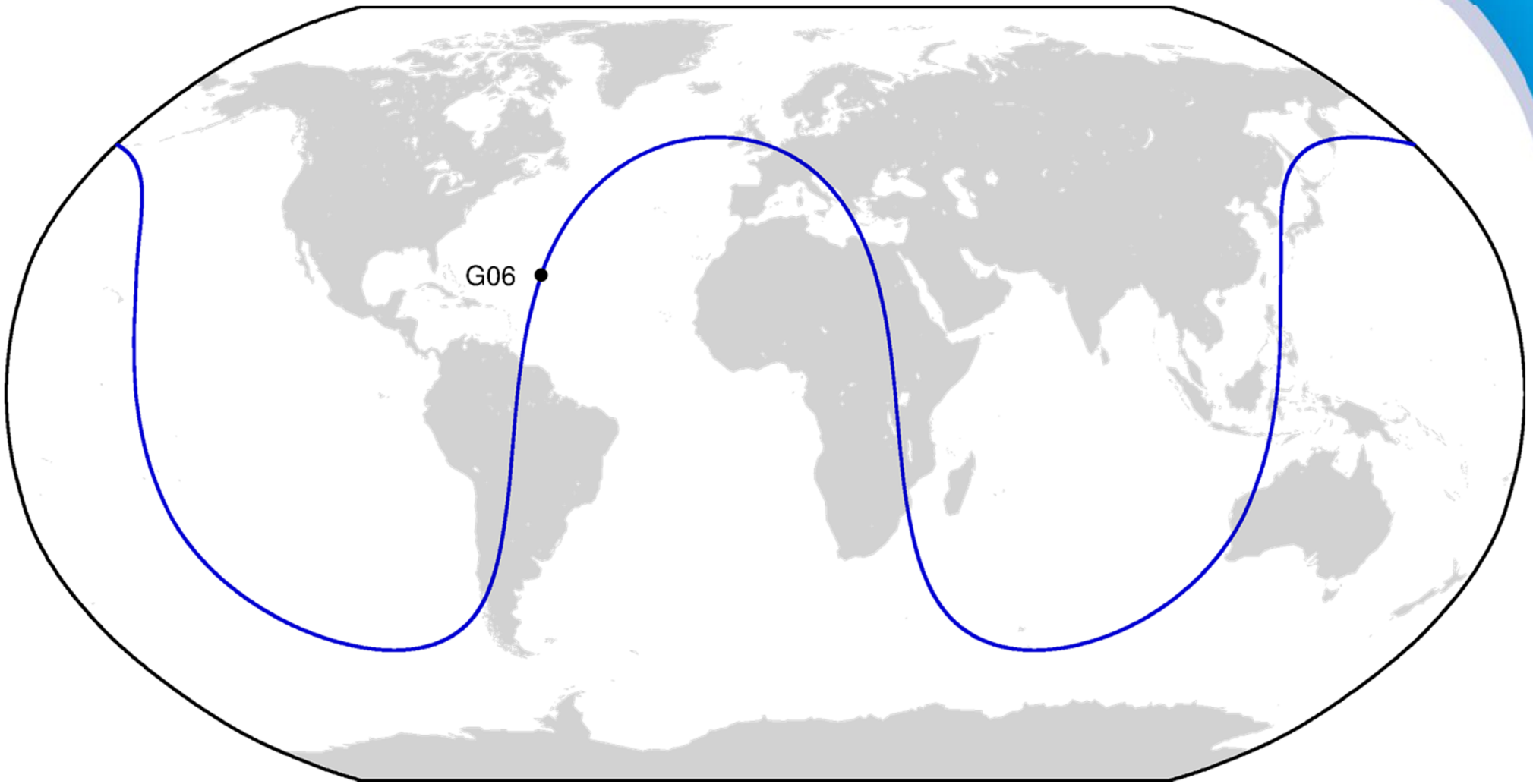


GPS constellation



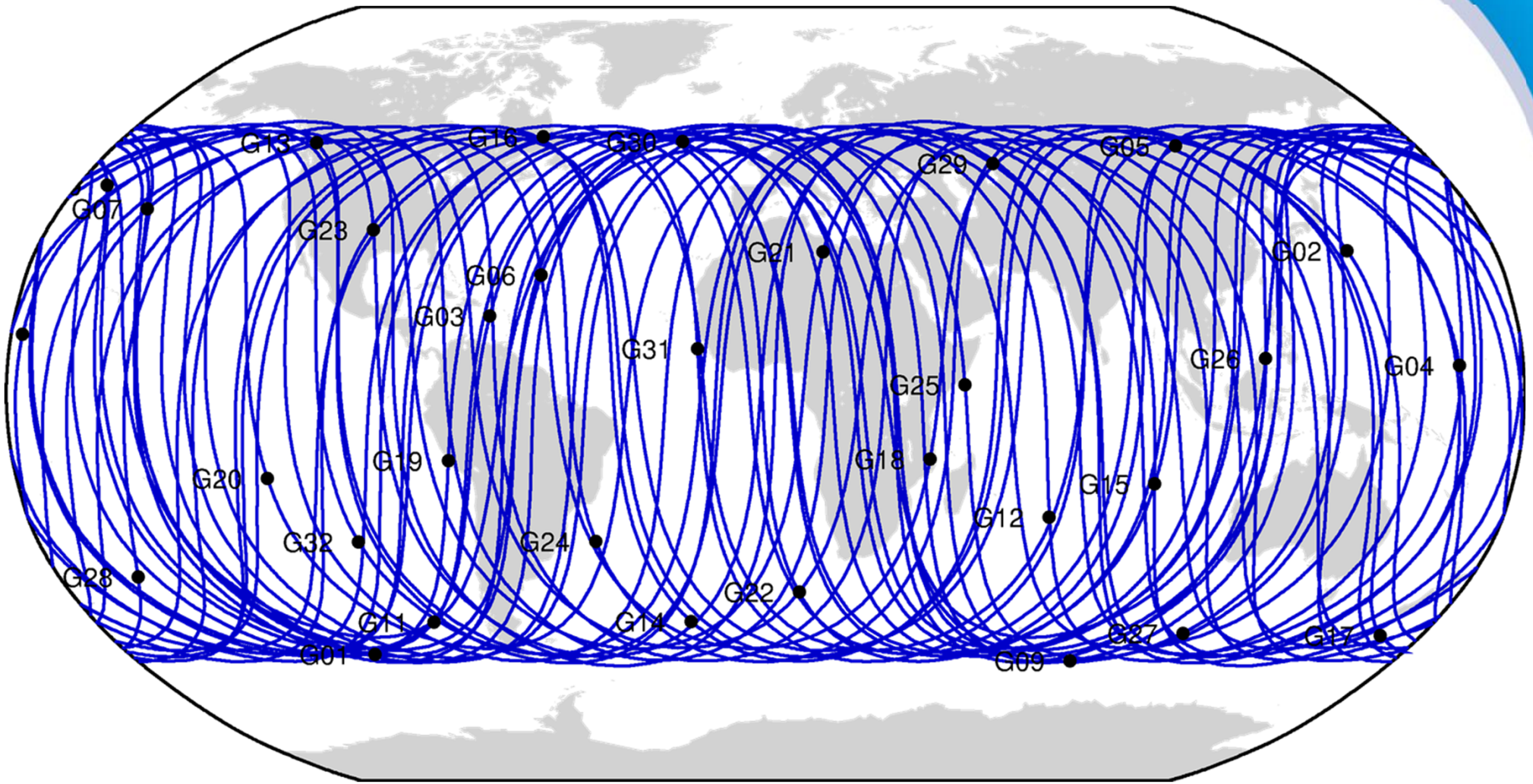
Ground track for G06 for 1 day (30-Mar-2012)

GPS constellation



Ground track for G06 for 10 days (30-Mar-2012 to 08-Apr-2012)

GPS constellation



Ground track for all GPS satellites for 10 days (30-Mar-2012 to 08-Apr-2012)

GLONASS constellation

Orbital elements for GLONASS satellites

Semi-major axis: $a \approx 25{,}510$ km

Eccentricity: $e \approx 0$ (circular orbit)

Inclination: $i \approx 65^{o}$

Orbital planes

Number of planes: 3 plane at $\Omega_n = \Omega_0 + n \cdot 120^{o}$

Satellites per plane: 8 regularly distributed

= 24 nominal constellation (currently 24 active)

Repetition rates

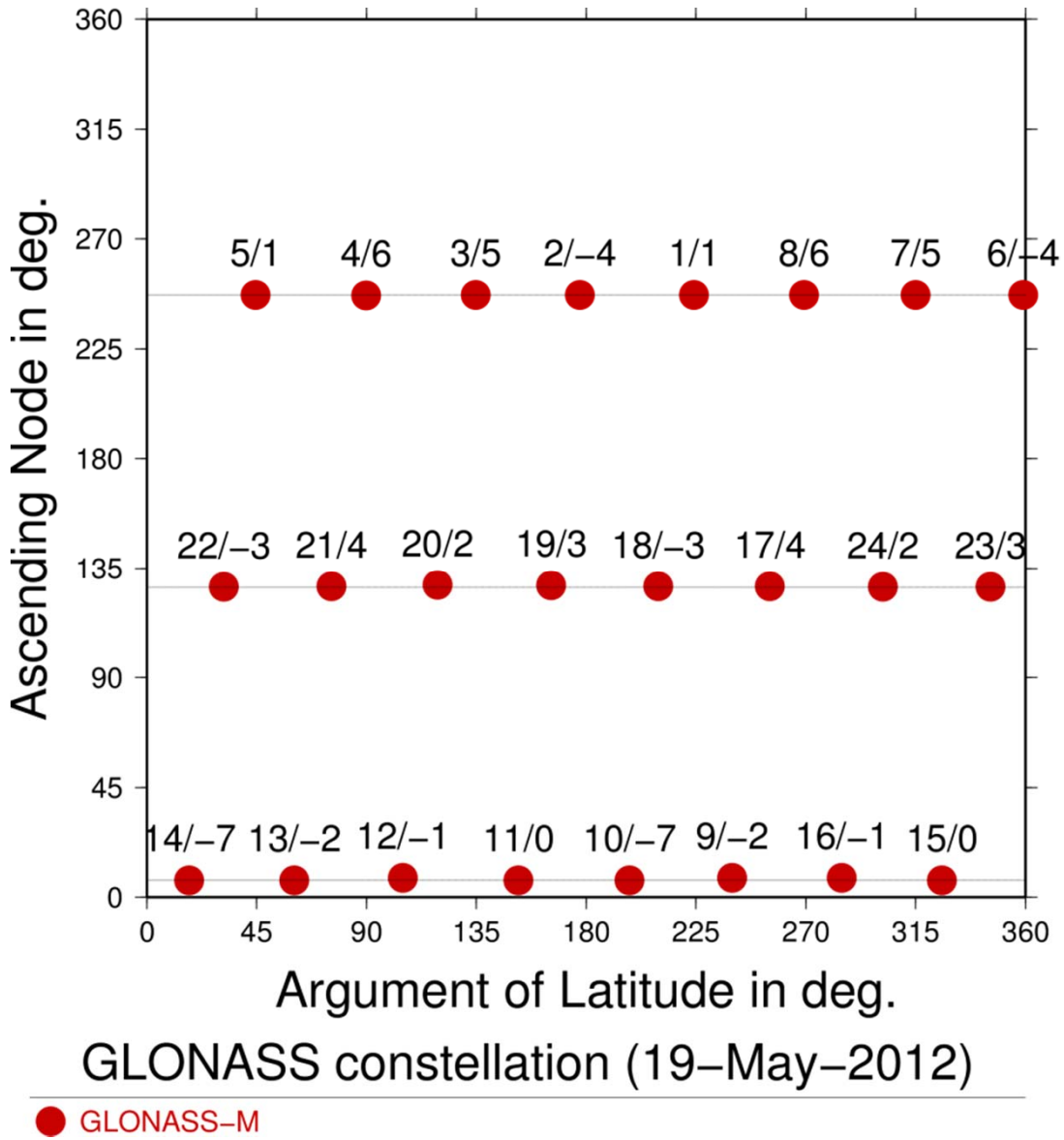
Revolution period: 11 h 16min

Repetition of the constellation: 8 sidereal day

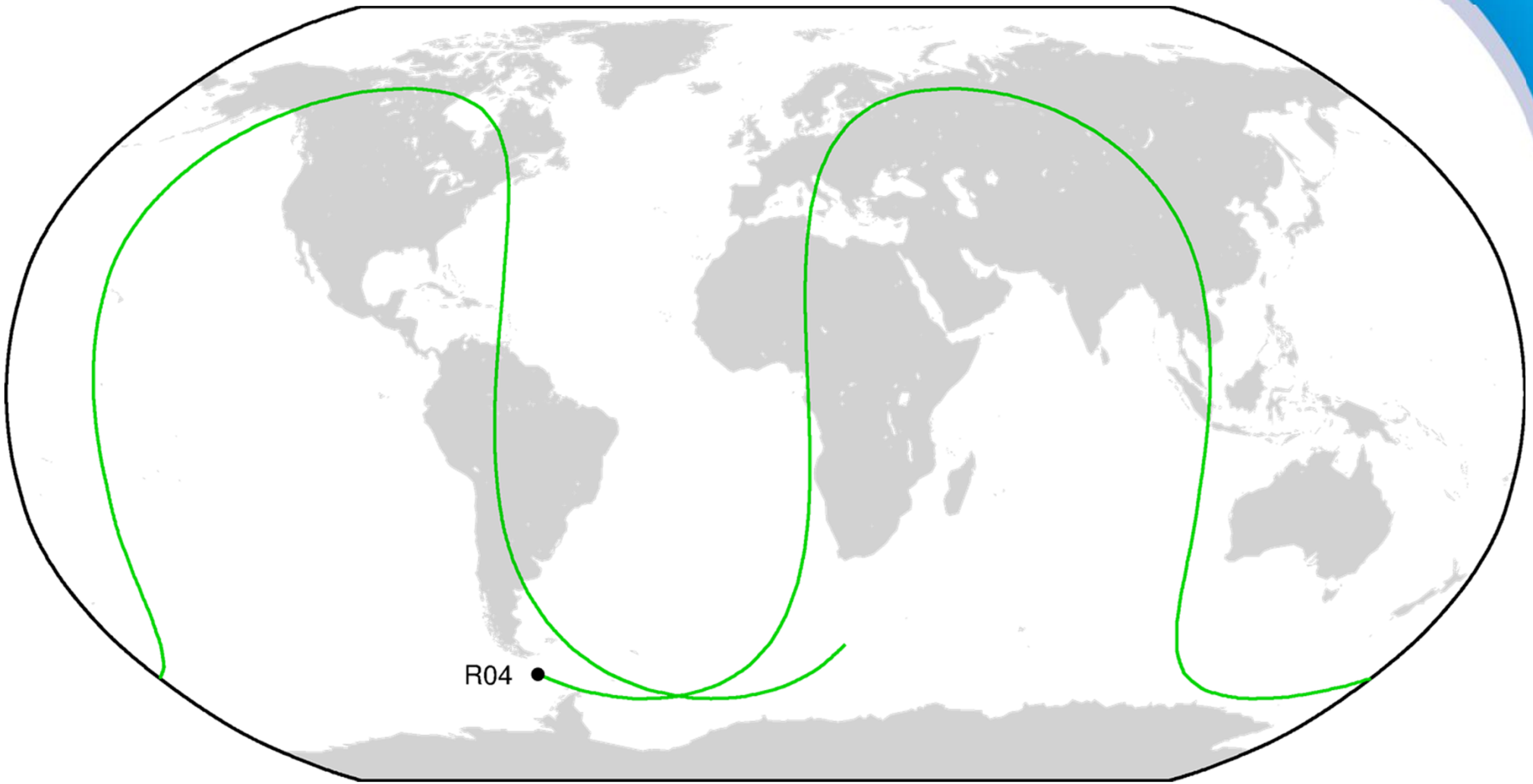
Repetition of the geometry: 1/3 sidereal day with the next plane

1 sidereal day with the same plane

GLONASS constellation

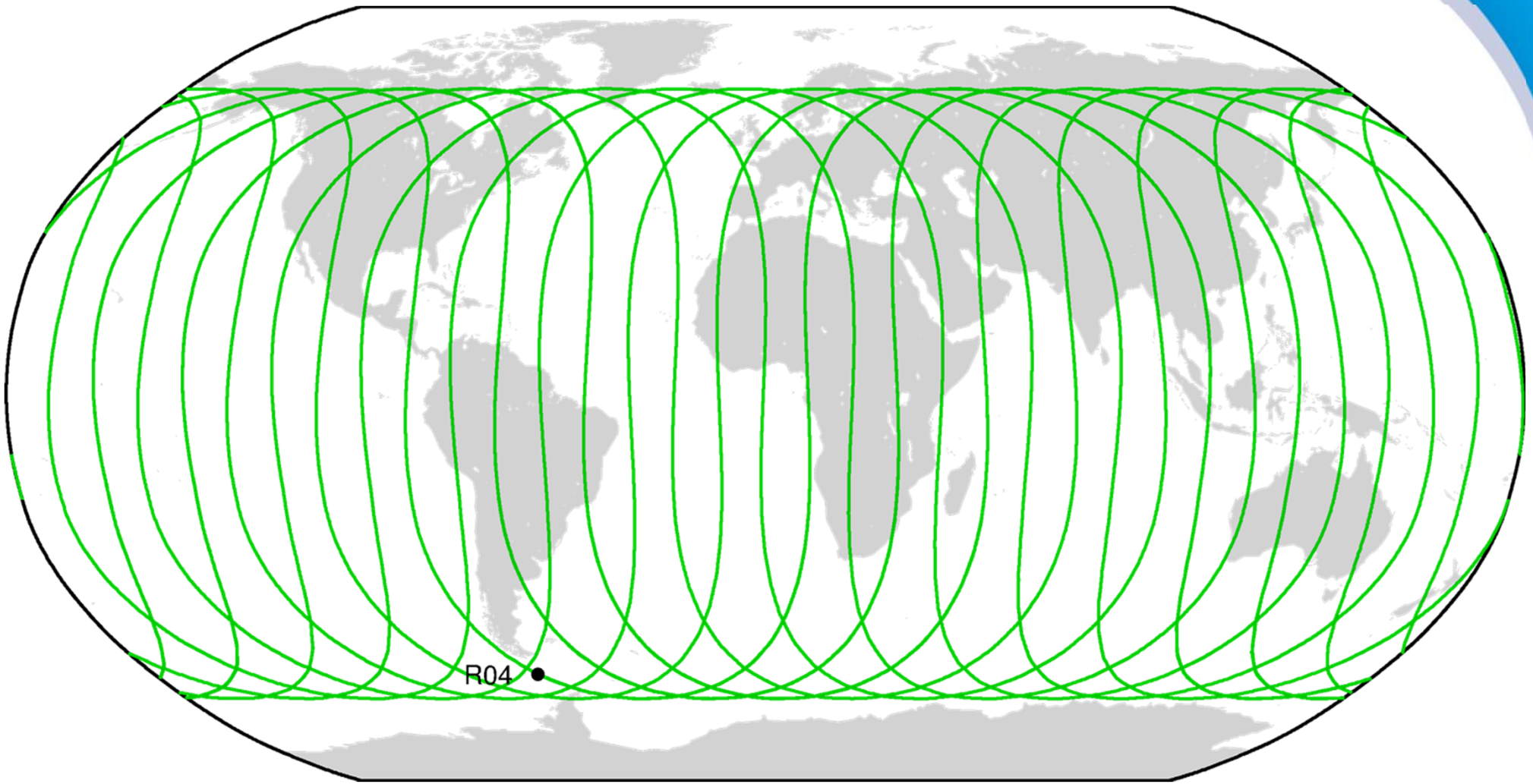


GLONASS constellation



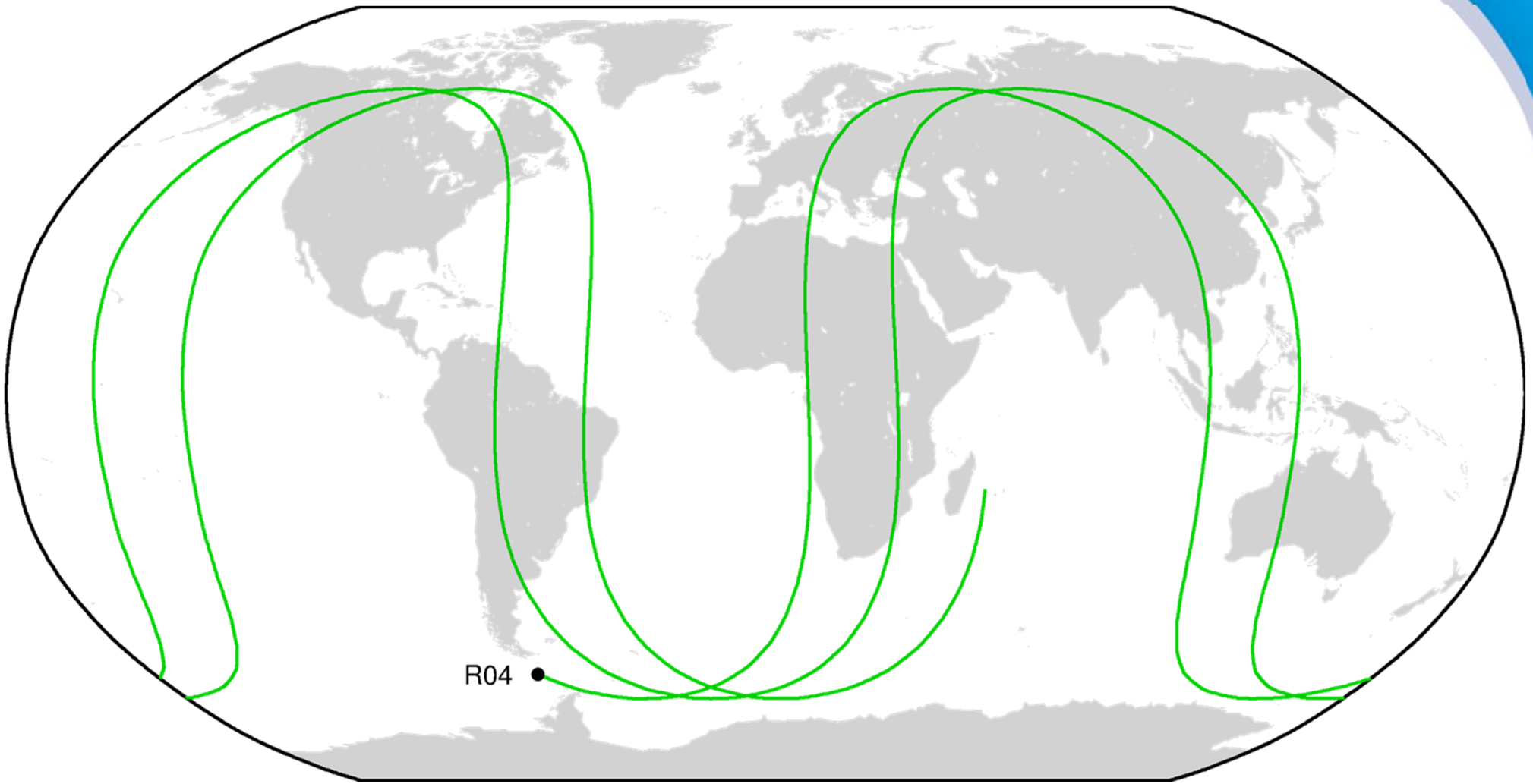
Ground track for R04 for 1 day (30-Mar-2012)

GLONASS constellation



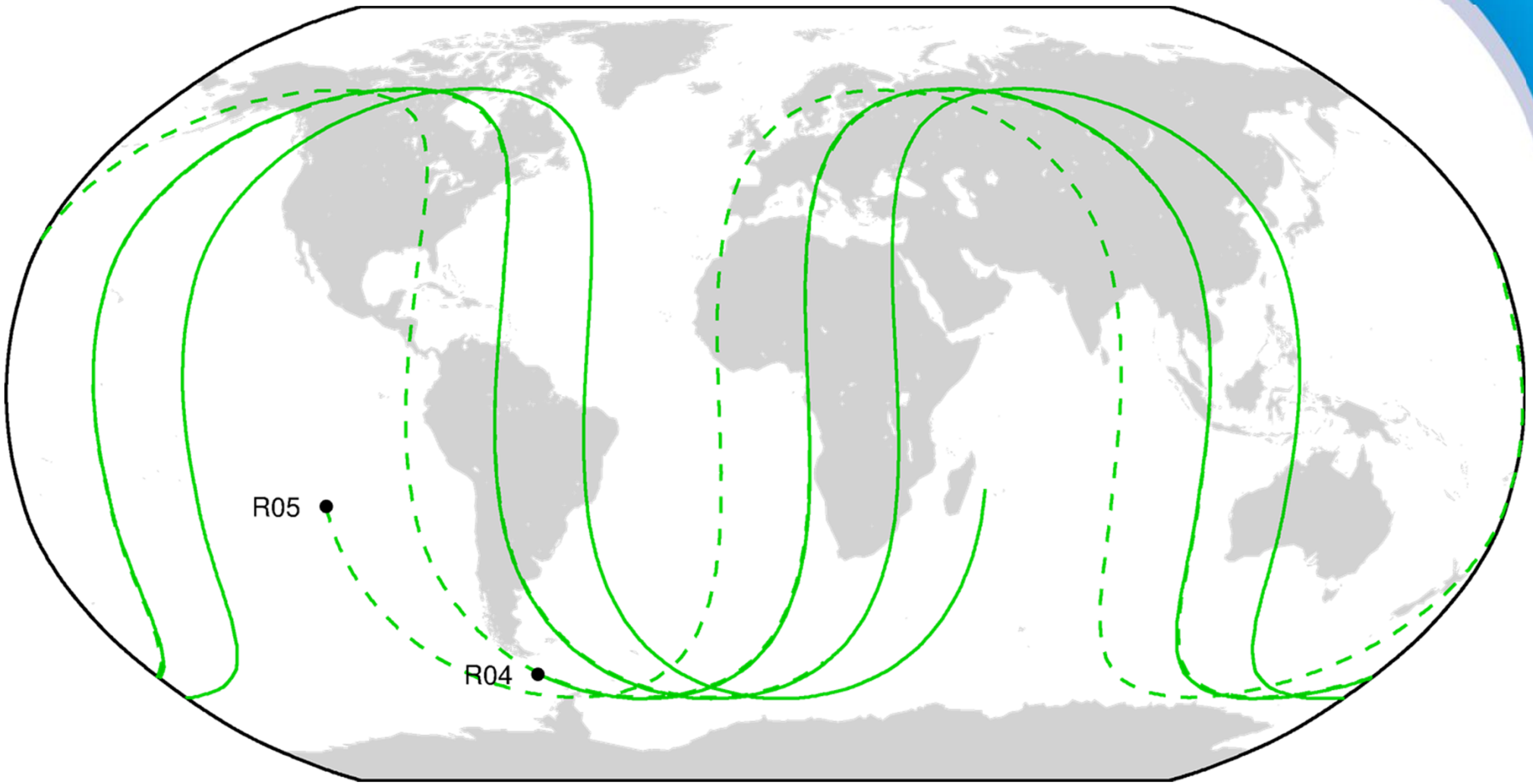
Ground track for R04 for 10 days (30-Mar-2012 to 08-Apr-2012)

GLONASS constellation



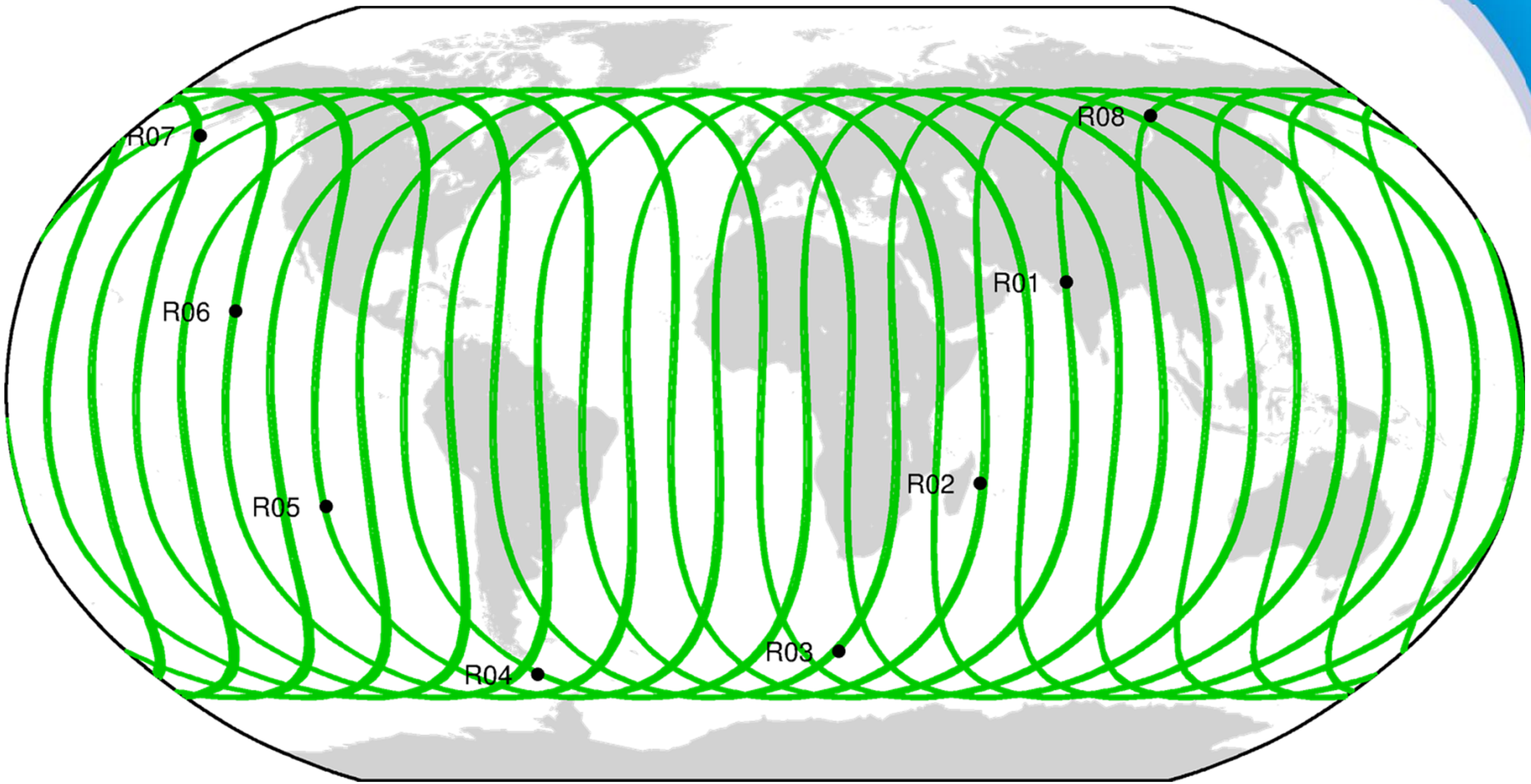
Ground track for R04 for 2 days (30-Mar-2012 to 31-Mar-2012)

GLONASS constellation



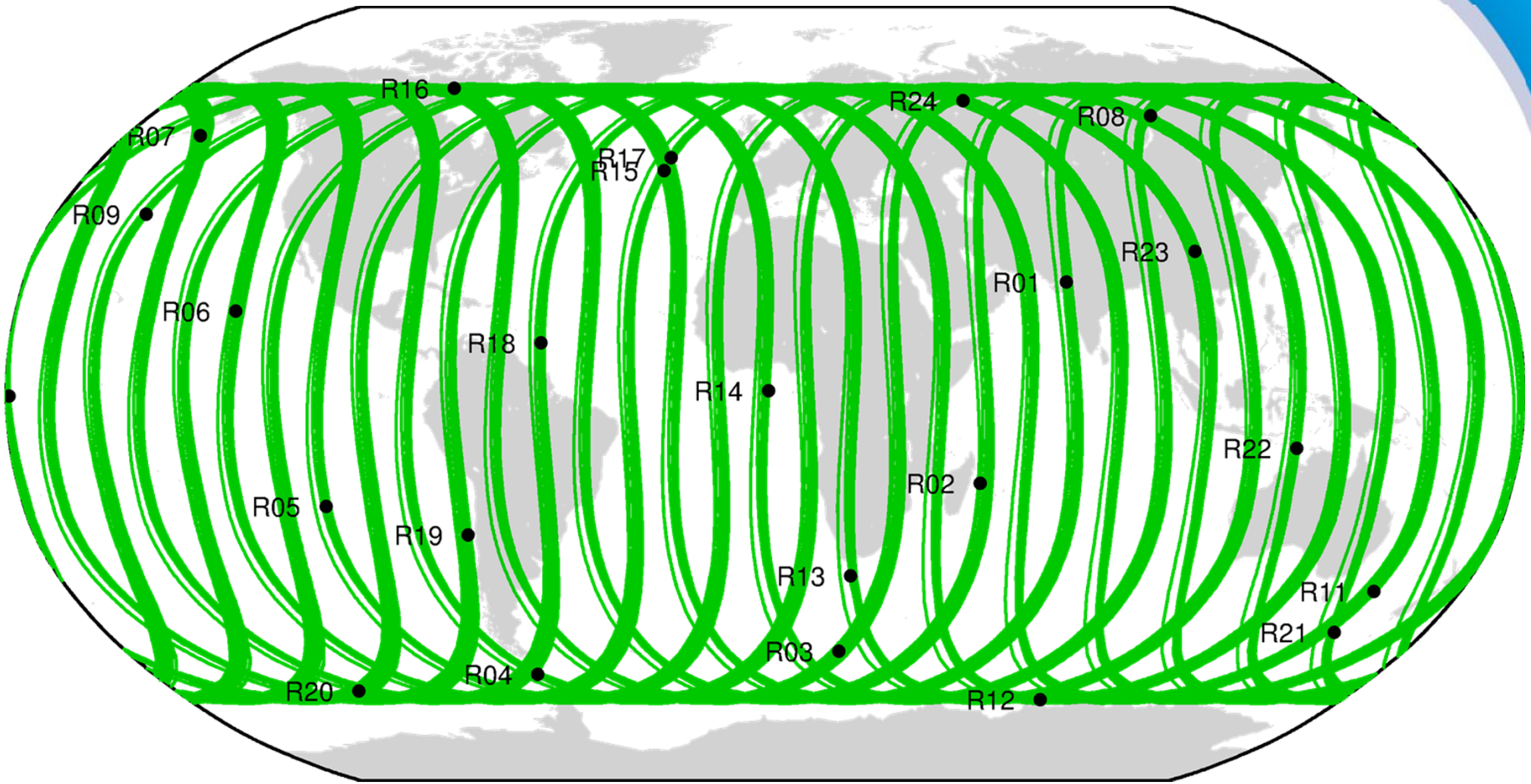
Ground track for R04 and R05 for 2 days (30-Mar-2012 to 31-Mar-2012)

GLONASS constellation



Ground track for R01 to R08 for 10 days (30-Mar-2012 to 08-Apr-2012)

GLONASS constellation



Ground track for all GLONASS satellites for 10 days (30-Mar-2012 to 08-Apr-2012)

Galileo constellation

Orbital elements for Galileo satellites

Semi-major axis: $a \approx 30{,}000$ km

Eccentricity: $e \approx 0$ (circular orbit)

Inclination: $i \approx 56^{o}$

Orbital planes

Number of planes: 3 plane at $\Omega_n = \Omega_0 + n \cdot 120^{o}$

Satellites per plane: 9 regularly distributed

= 27 nominal constellation

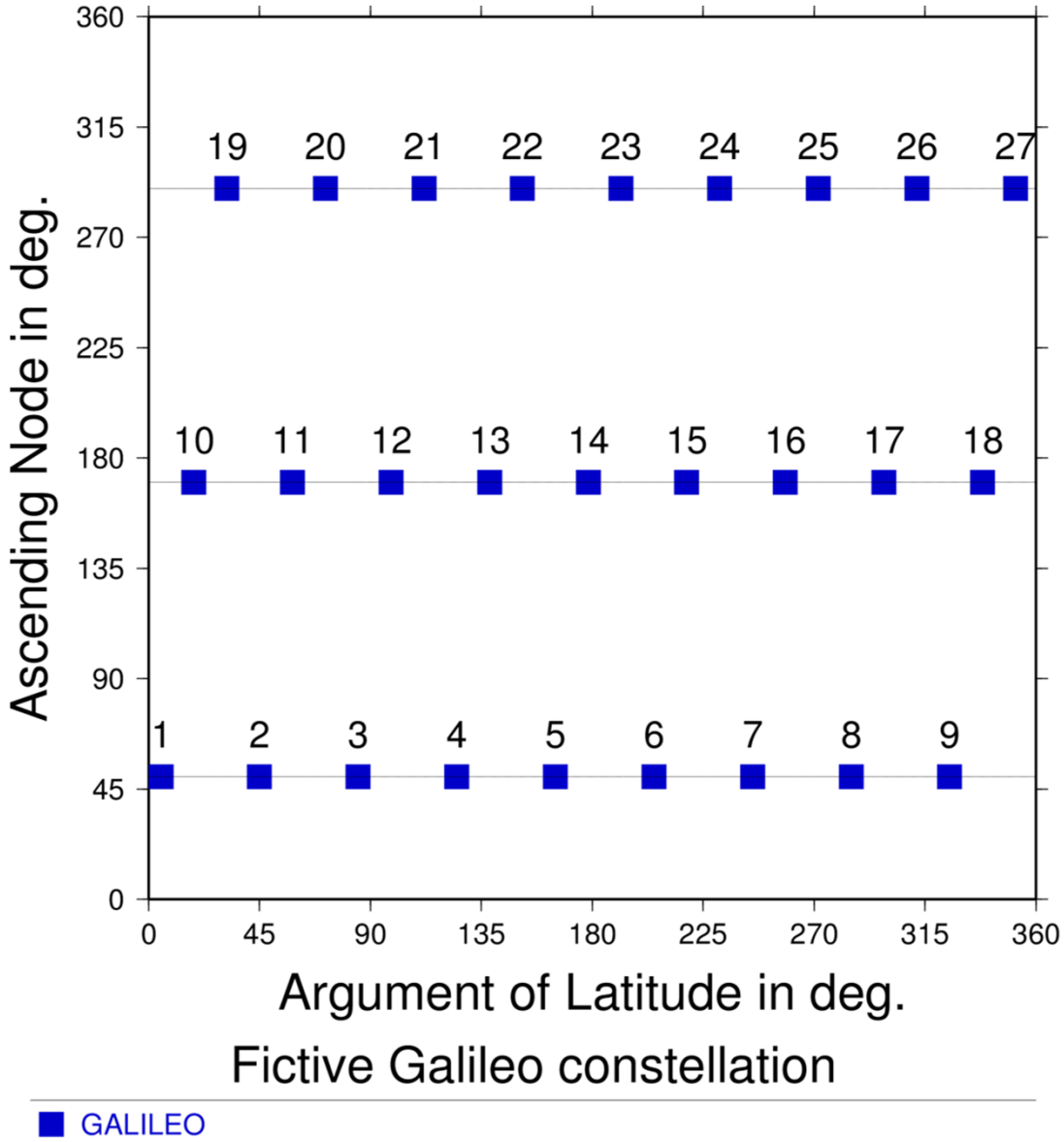
Repetition rates

Revolution period: 13 h 45min

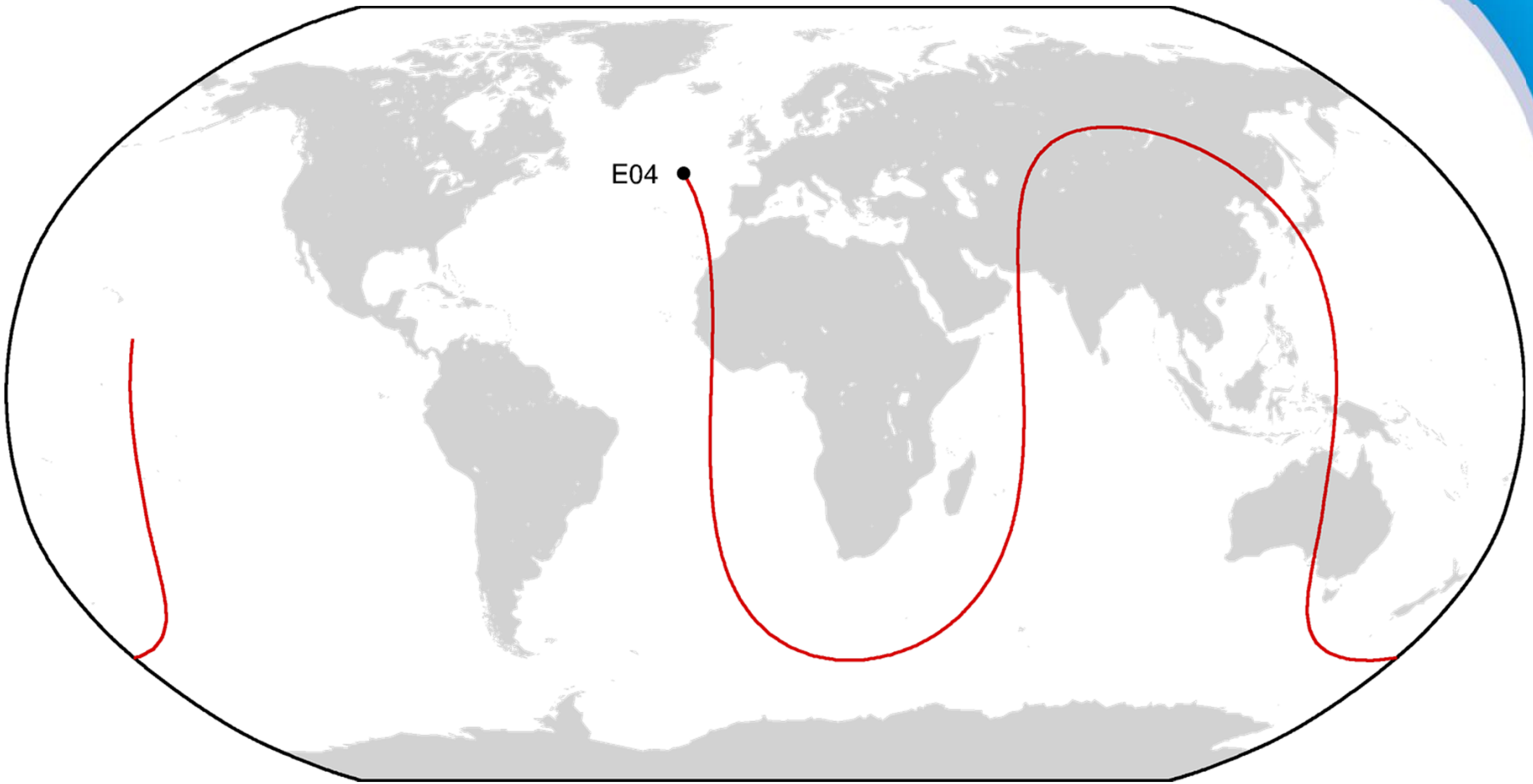
Repetition of the constellation: 10 sidereal day

Repetition of the geometry: 10 sidereal day with the same plane

Galileo constellation

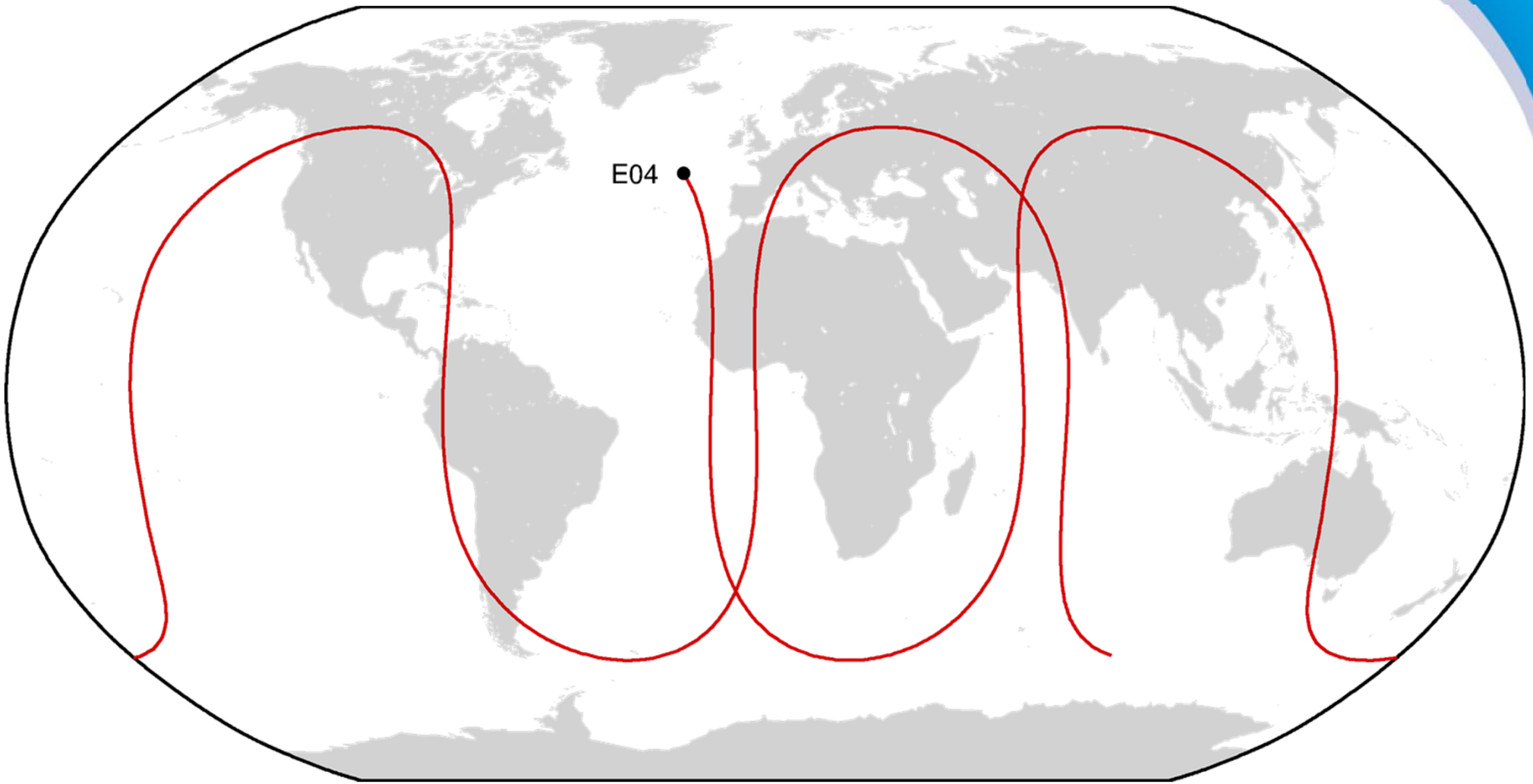


Galileo constellation



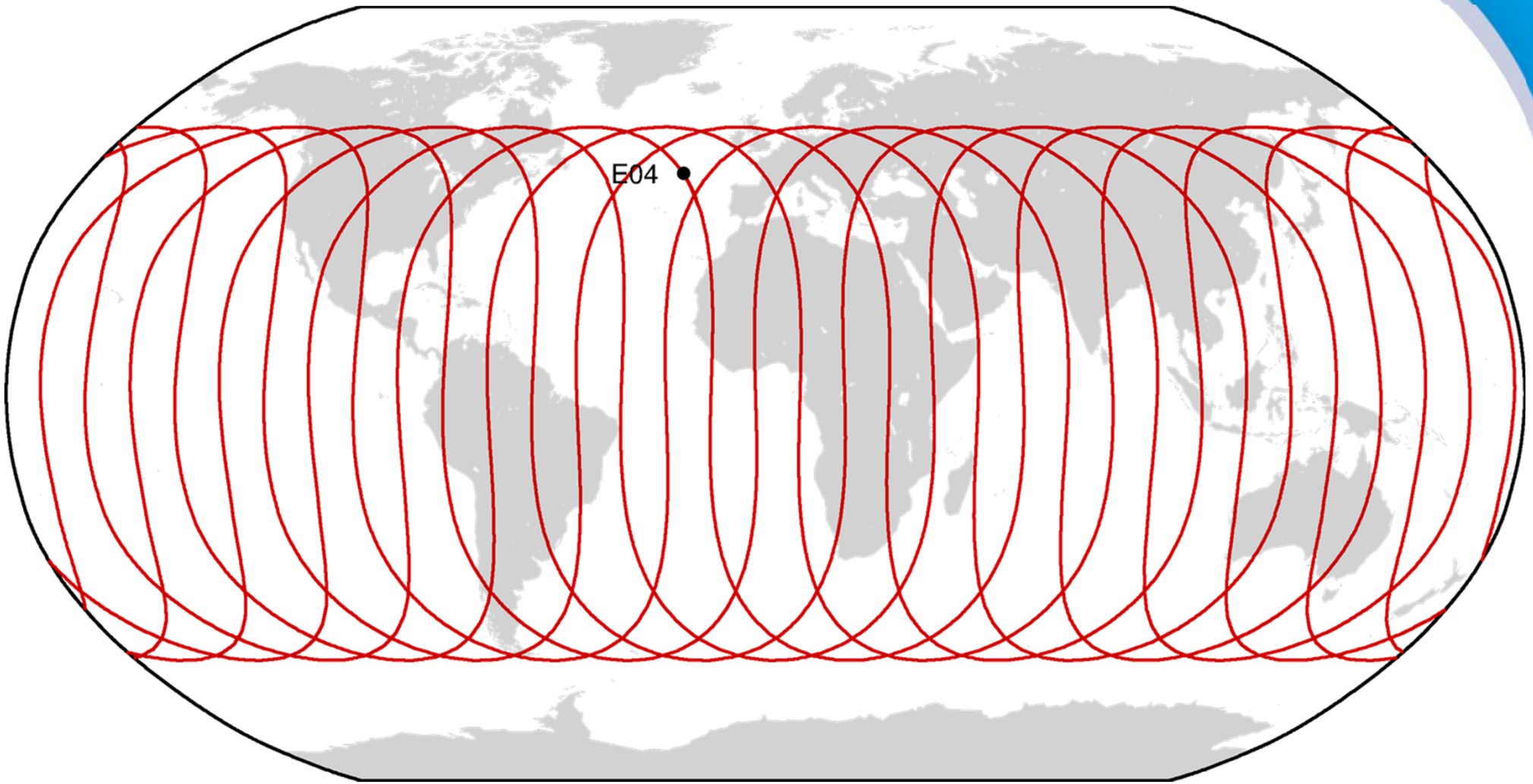
Ground track for E04 for 1 day (fictive constellation)

Galileo constellation



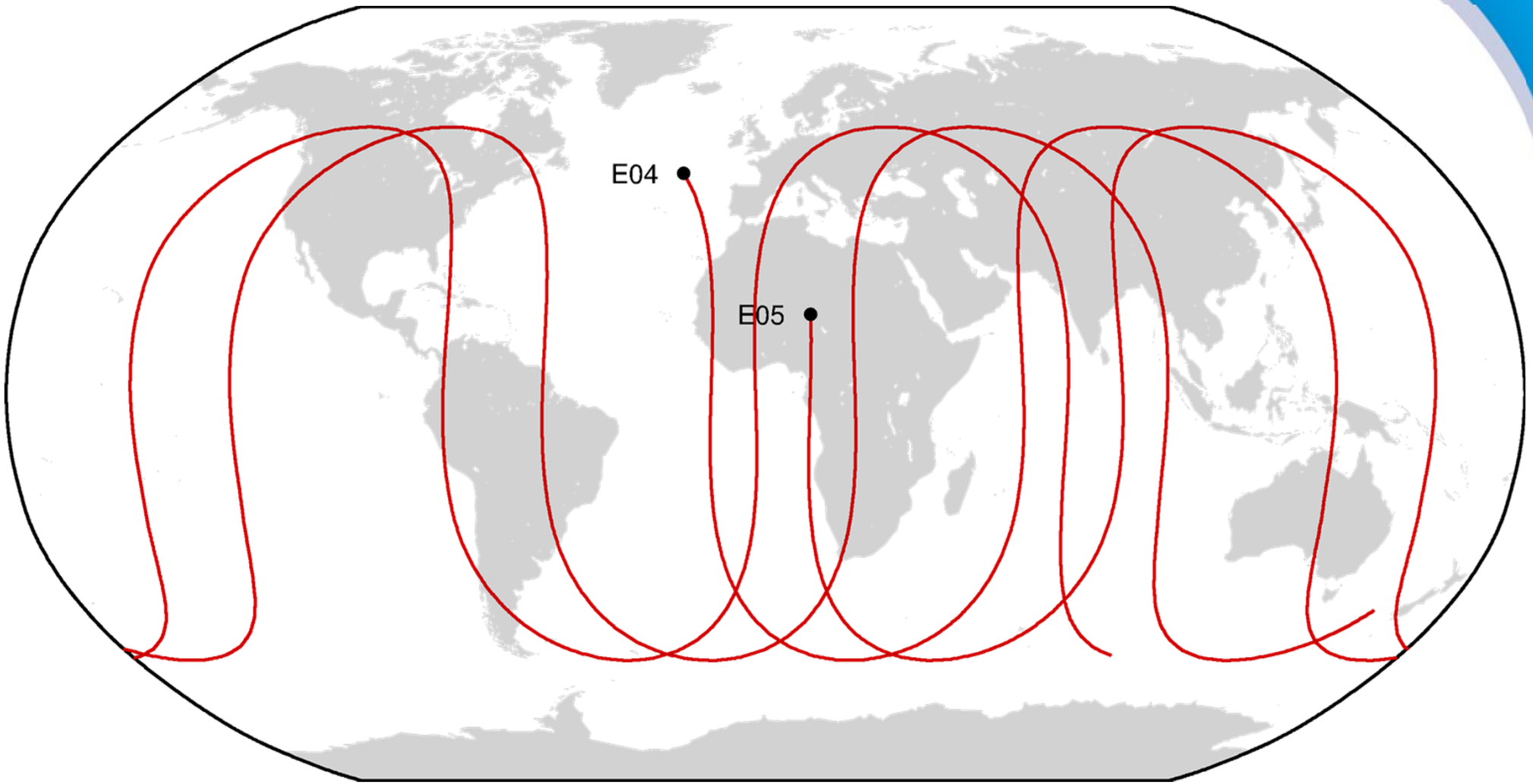
Ground track for E04 for 2 days (fictive constellation)

Galileo constellation



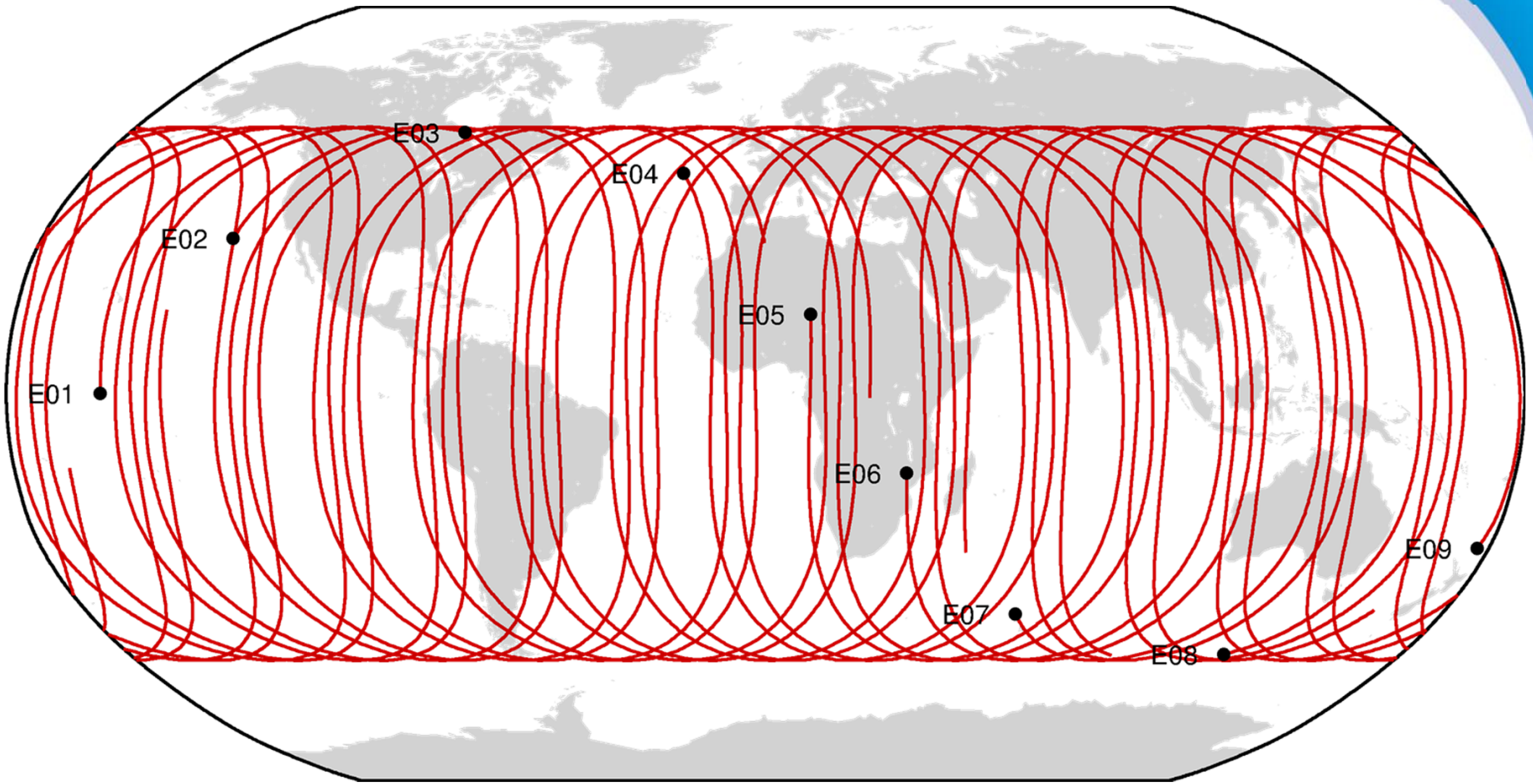
Ground track for E04 for 10 days (fictive constellation)

Galileo constellation



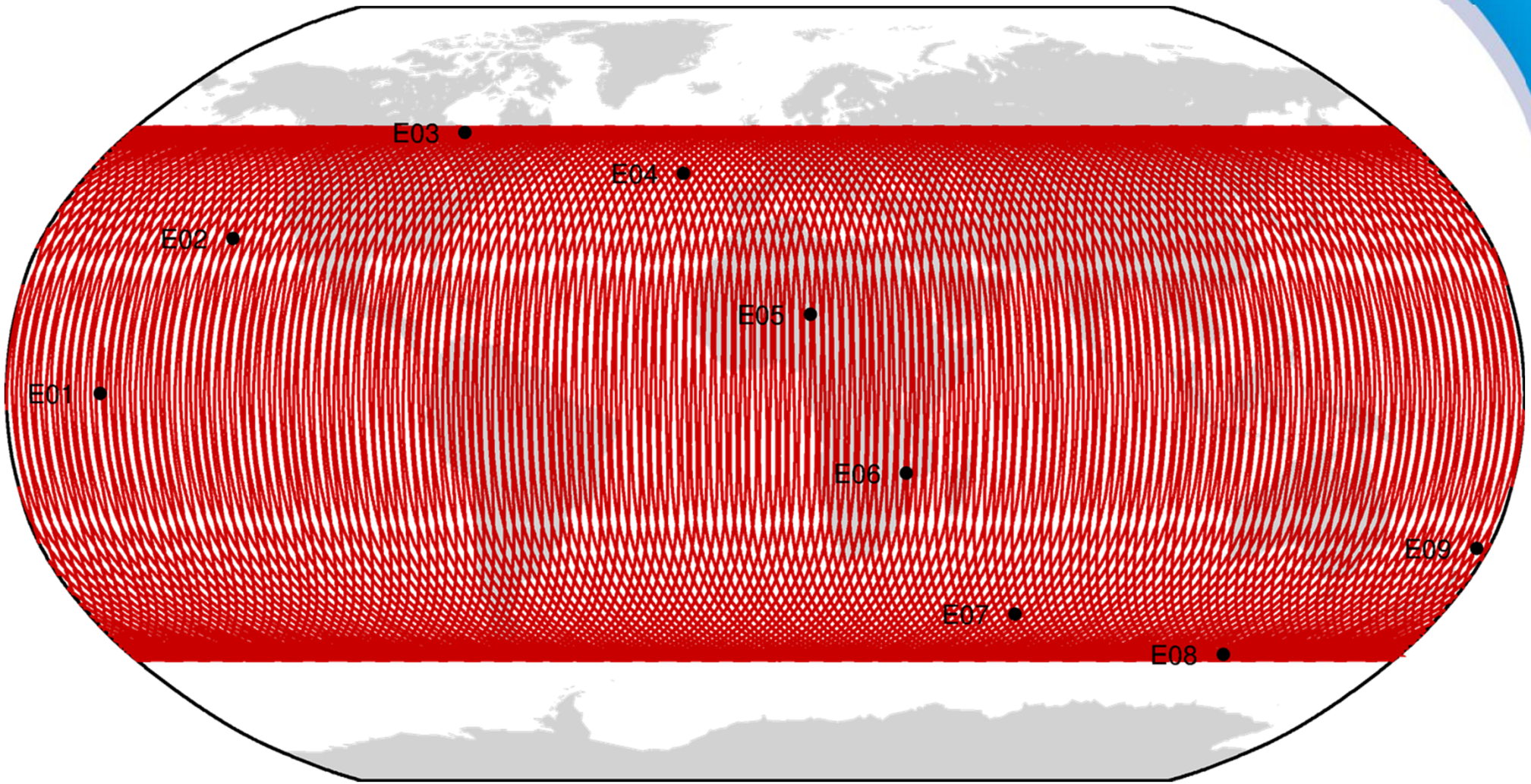
Ground track for E04 and E05 for 2 days (fictive constellation)

Galileo constellation



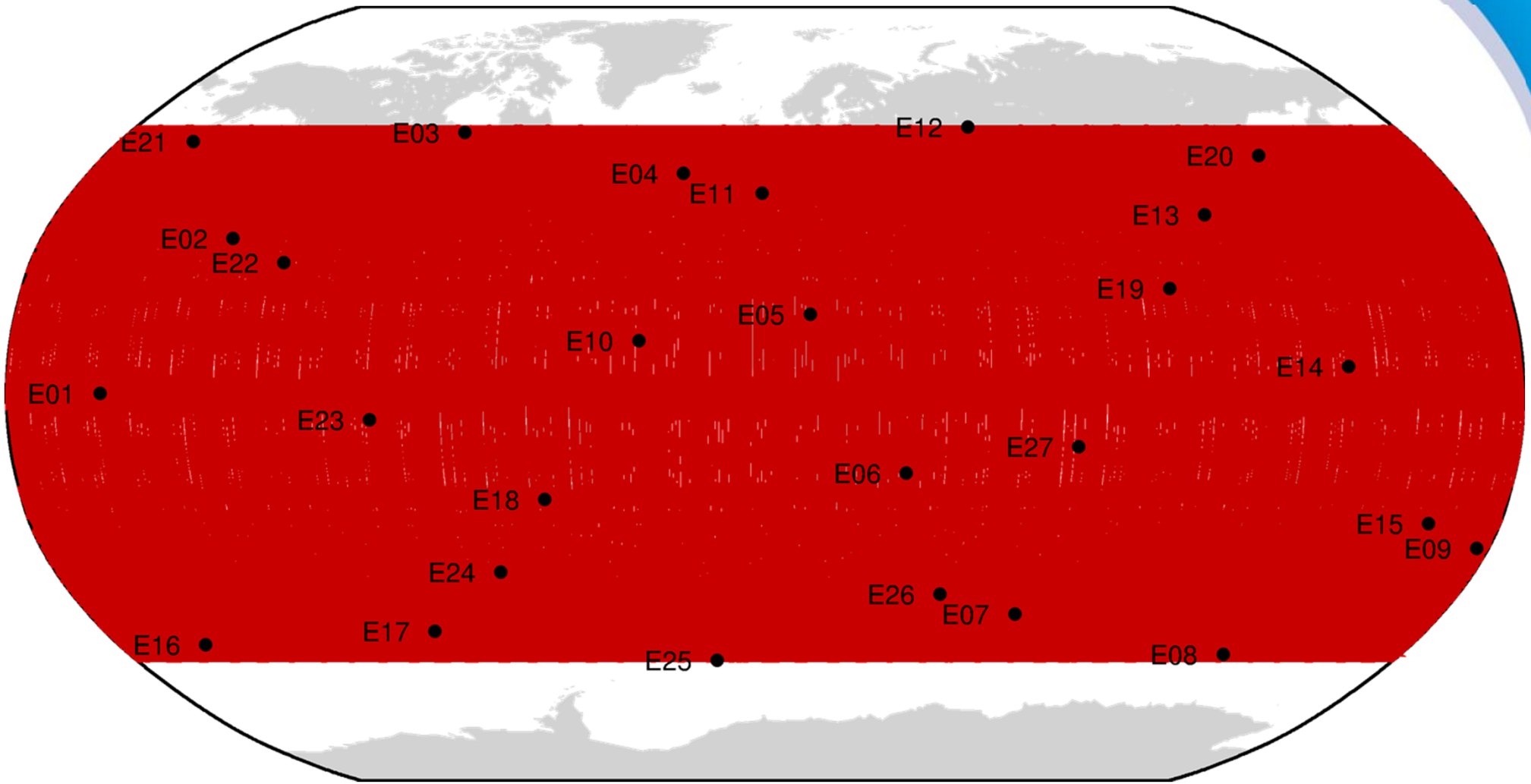
Ground track for E01 to E09 for 2 days (fictive constellation)

Galileo constellation



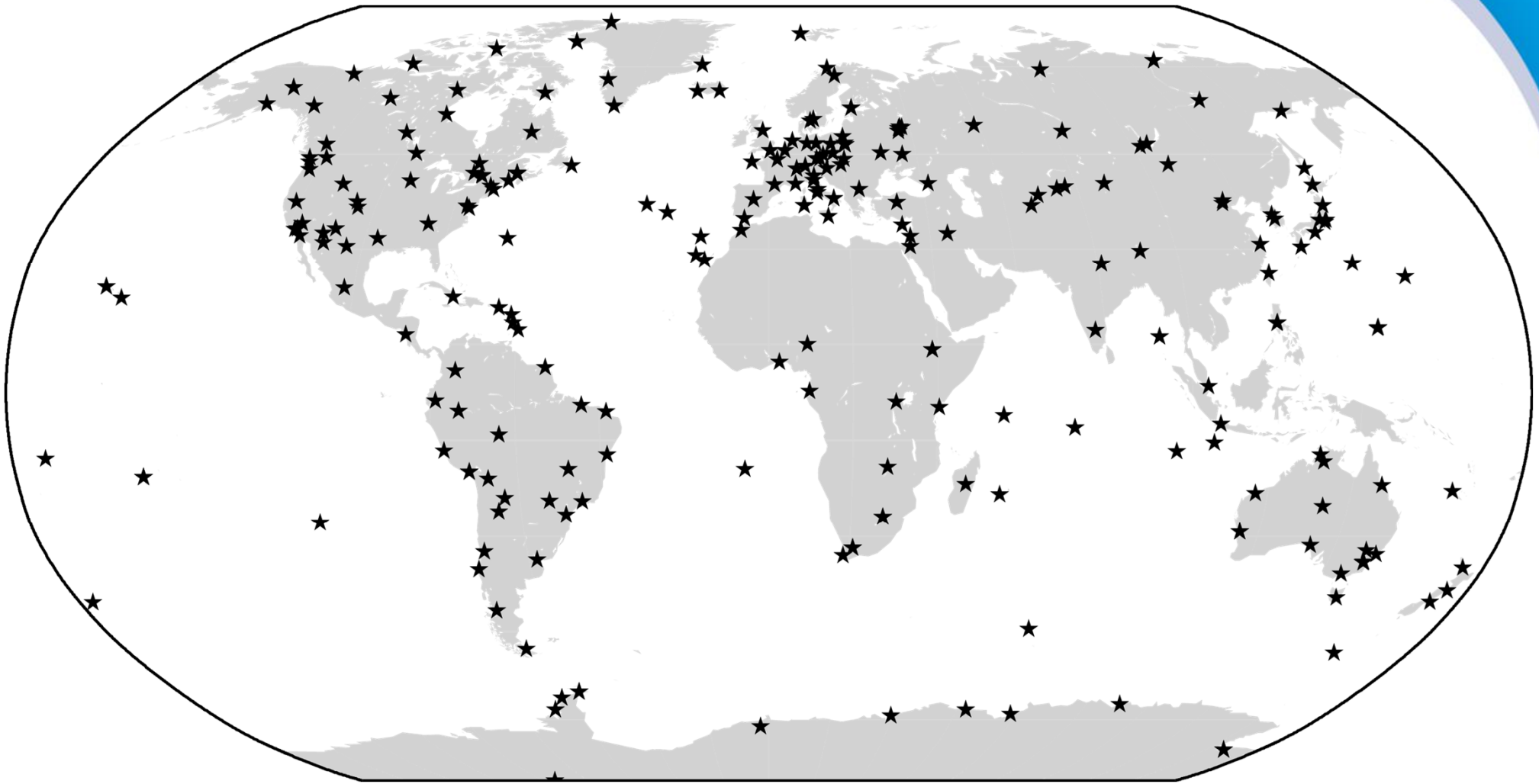
Ground track for E01 to E09 for 10 days (fictive constellation)

Galileo constellation



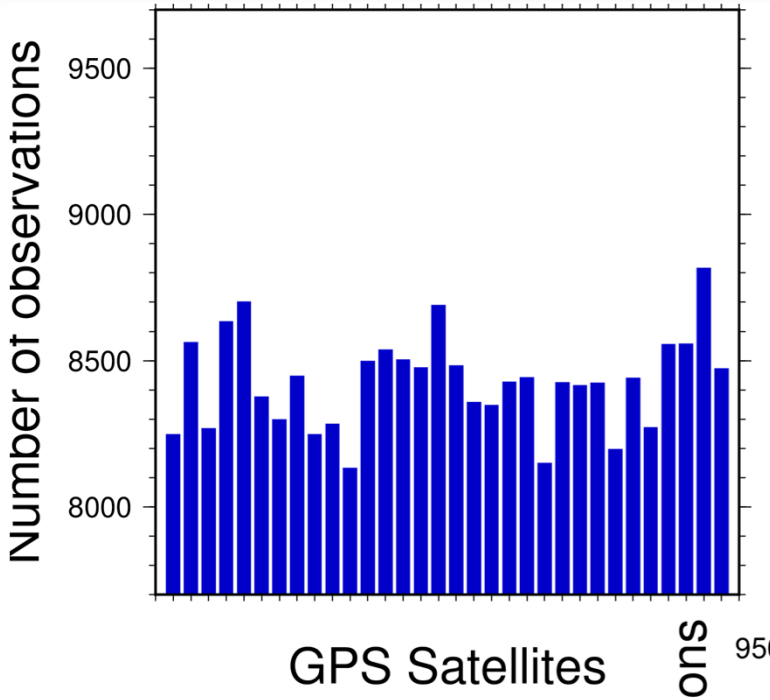
Ground track for all Galileo satellites for 10 days (fictive constellation)

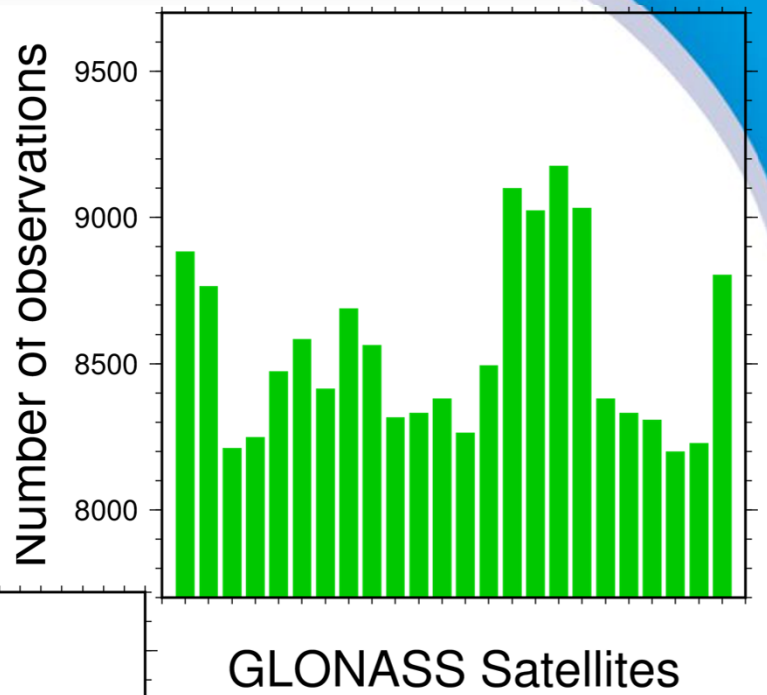
Global tracking network

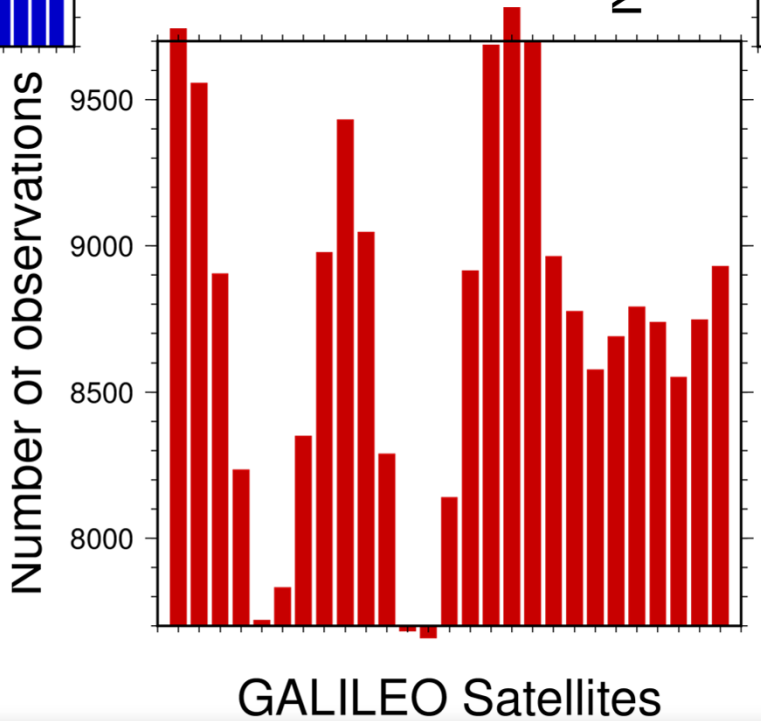


250 IGS stations (assuming that all stations observe all available satellites)

Number of observations per satellite

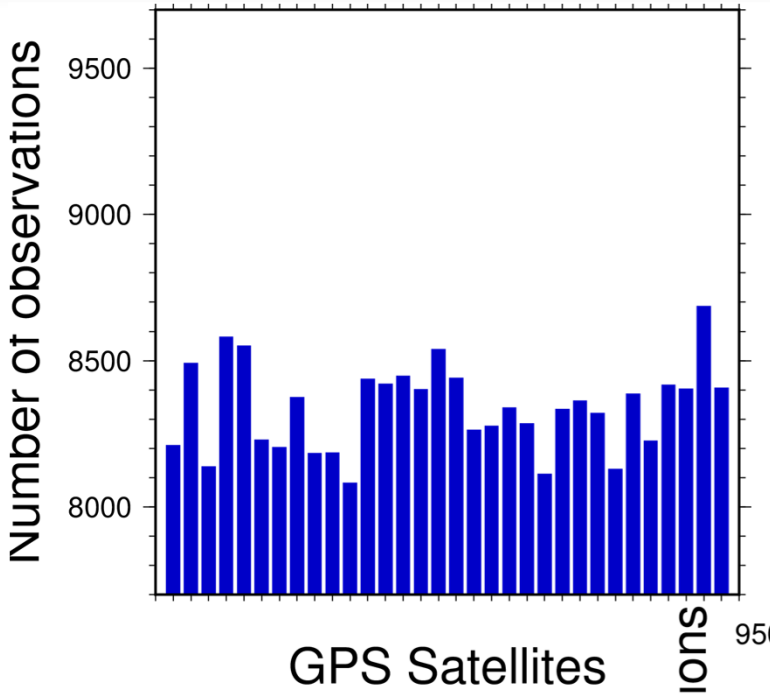


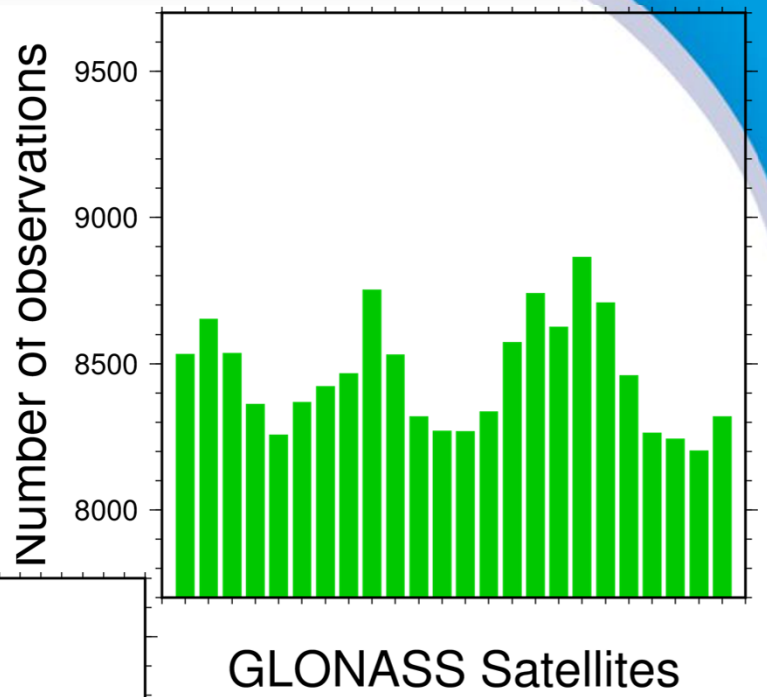


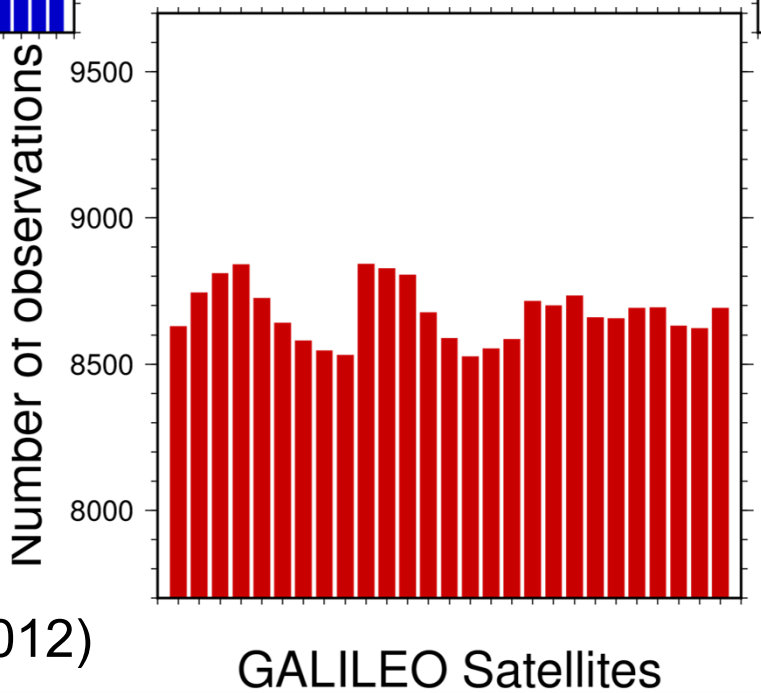


1 day (30-Mar-2012)

Number of observations per satellite

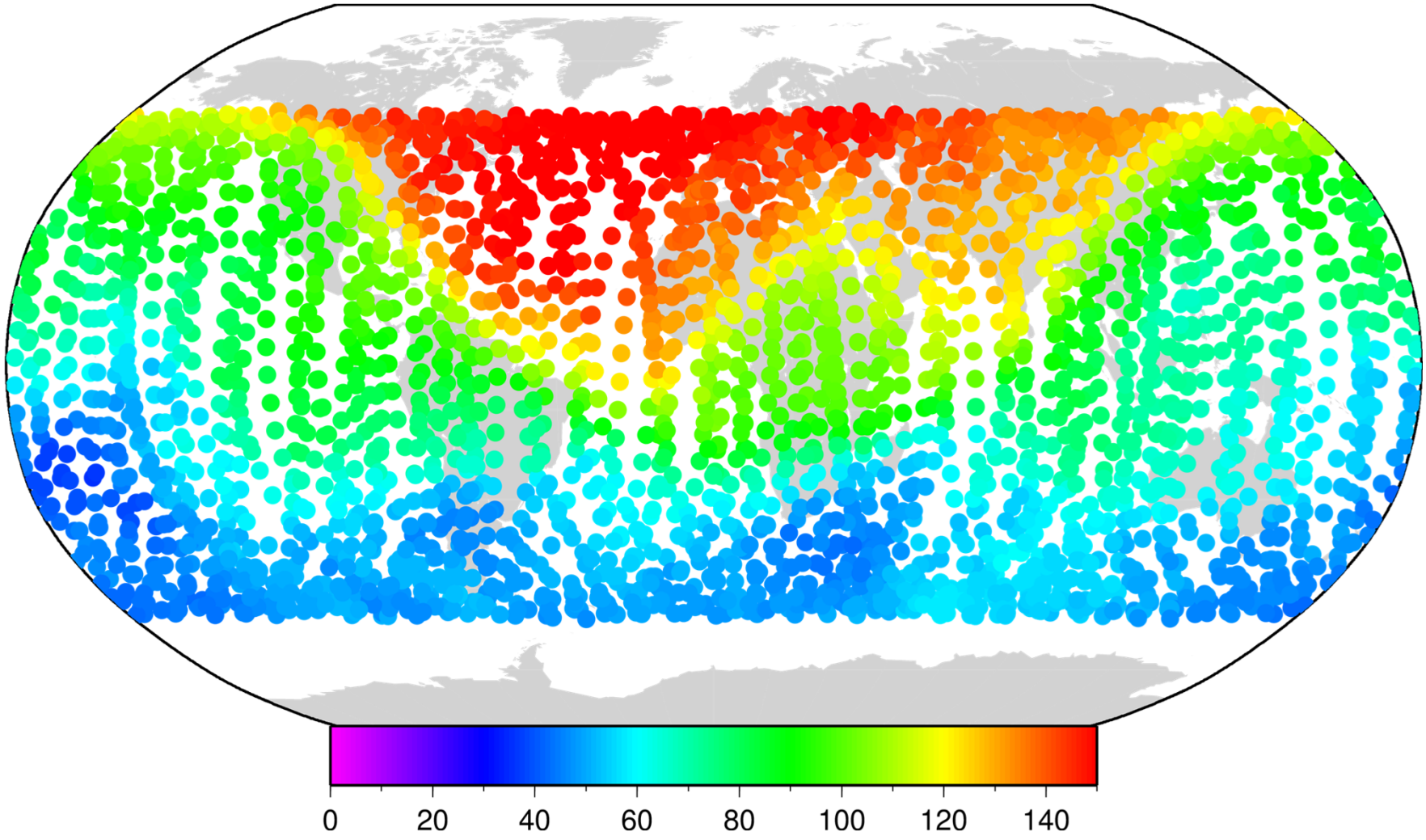






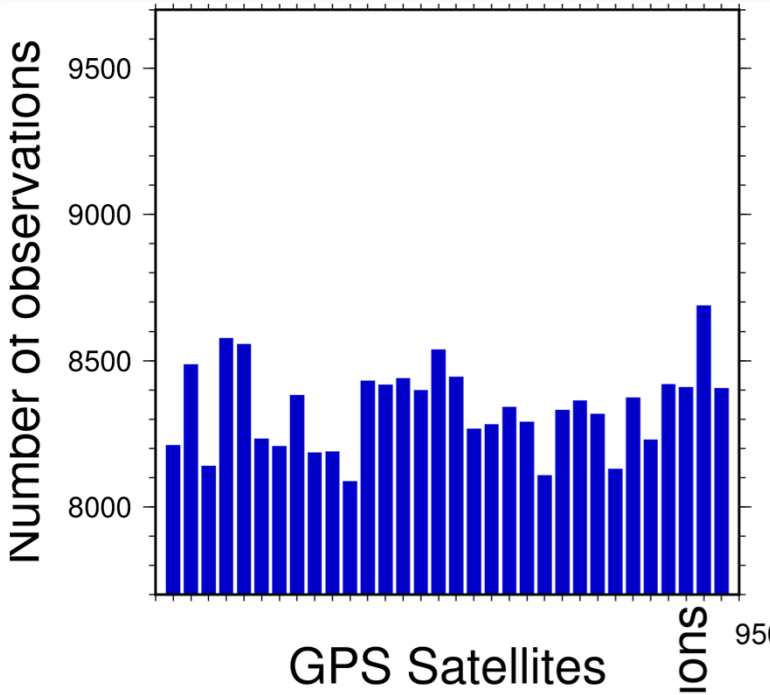
3 days (30-Mar to 01-Apr-2012)

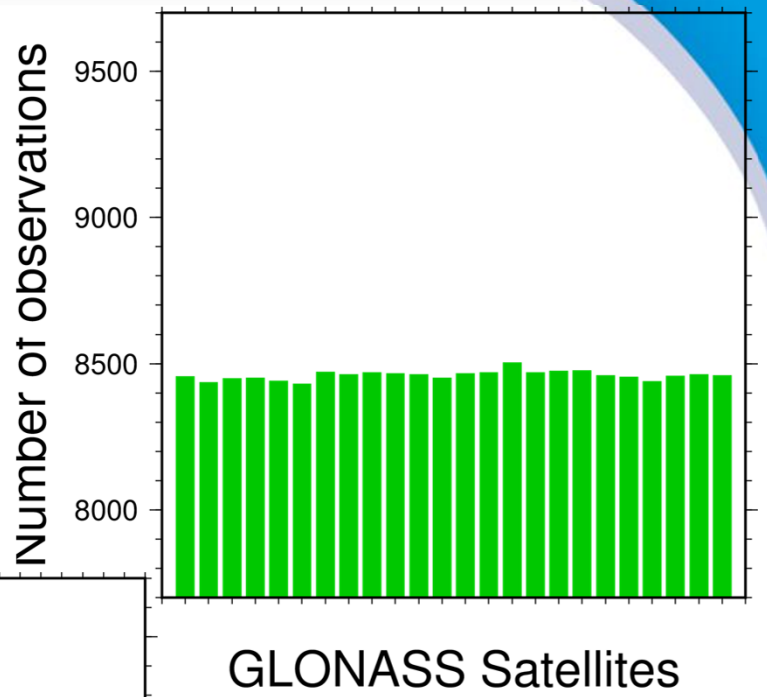
Number of observations per satellite

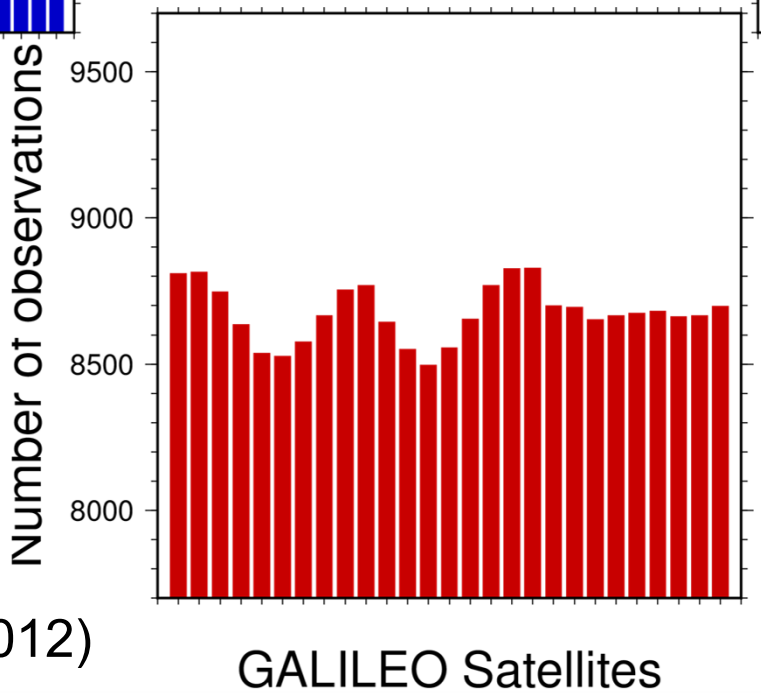


1 day (30-Mar-2012)

Number of observations per satellite

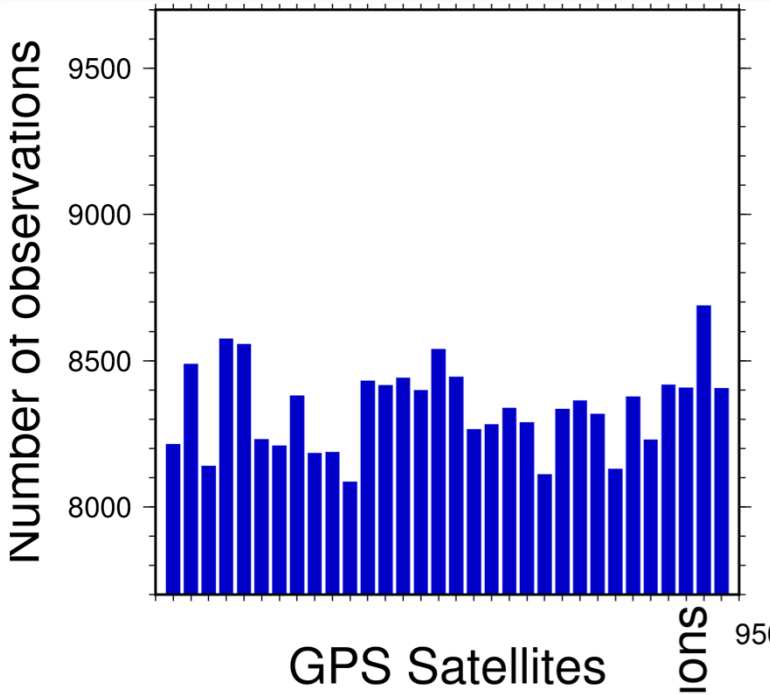


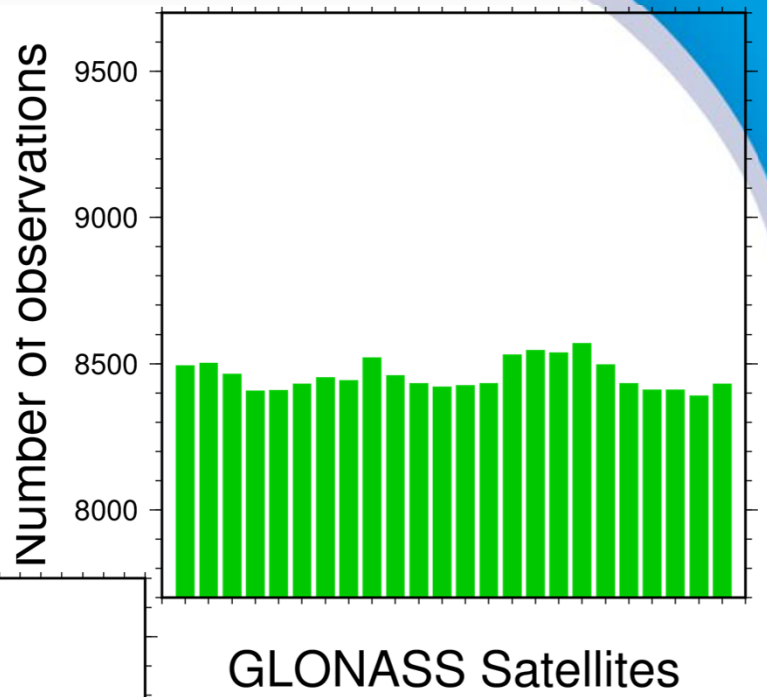


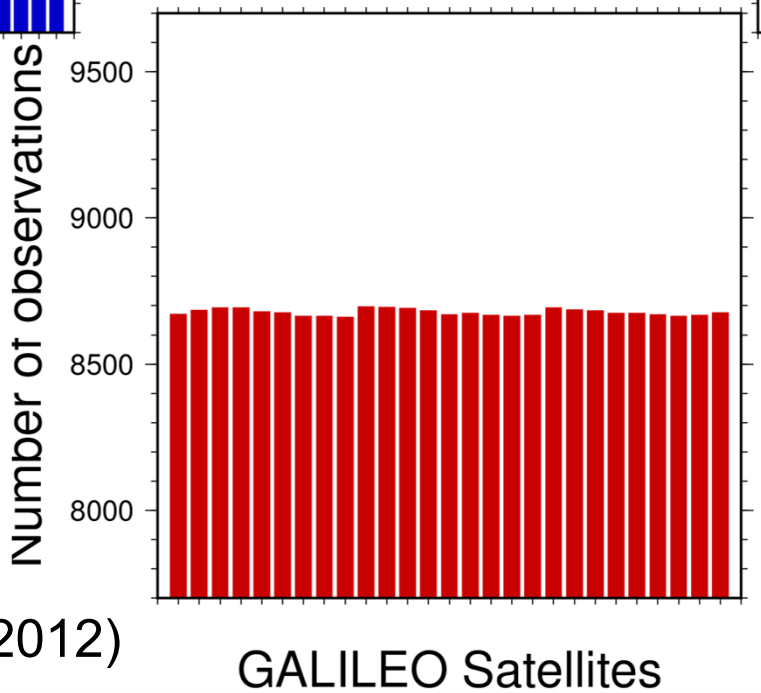


8 days (30-Mar to 06-Apr-2012)

Number of observations per satellite



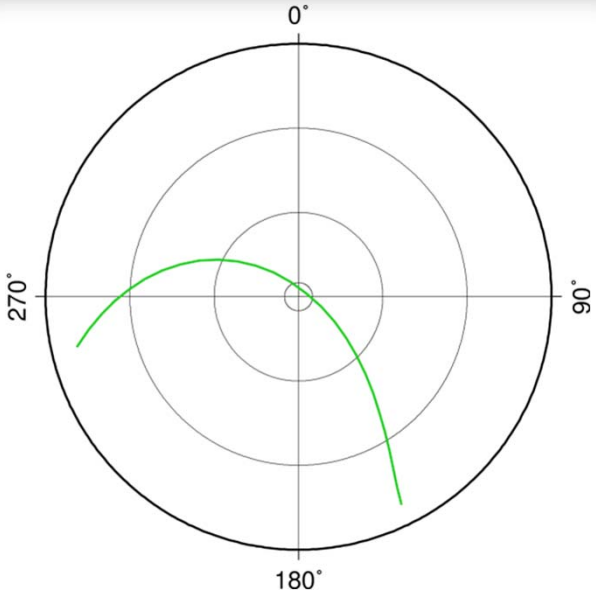


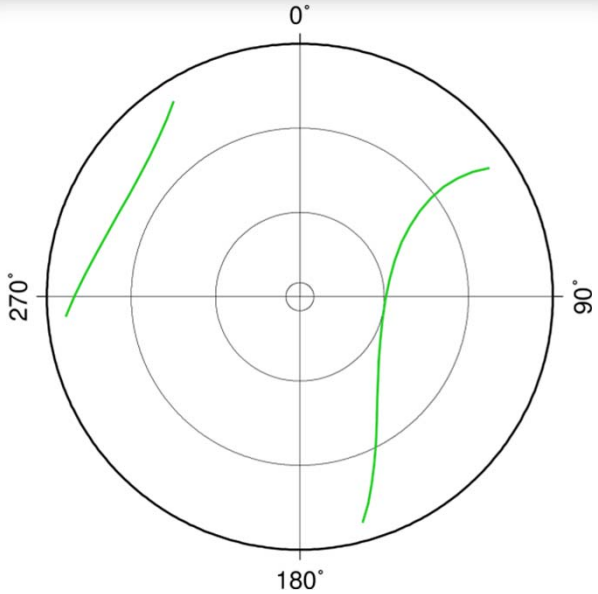


10 days (30-Mar to 08-Apr-2012)

Satellite visibility: GPS

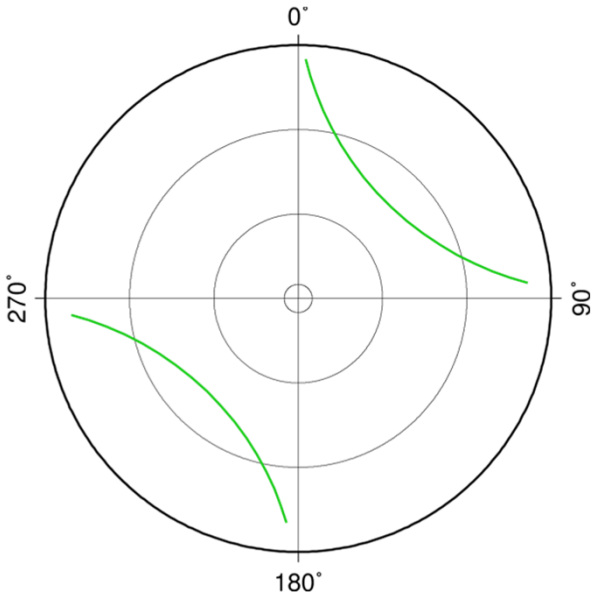
Zimmerwald
(Switzerland)
mid-latitude

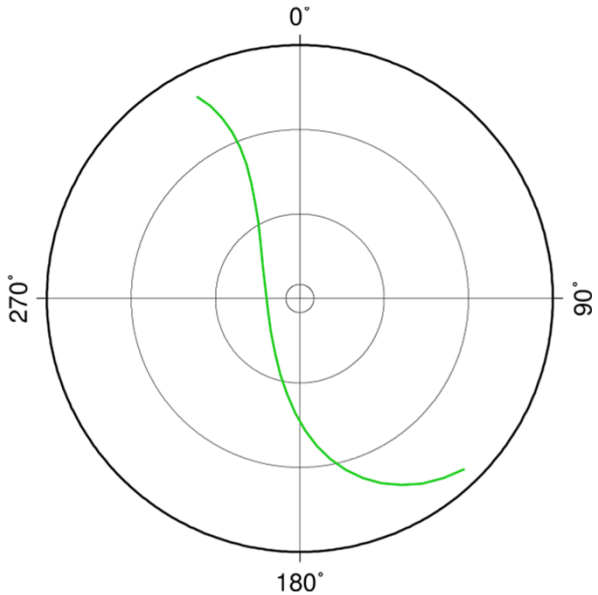




Algonquin
(Canada)
mid-latitude

Amundson-Scott
(South pole)
pole



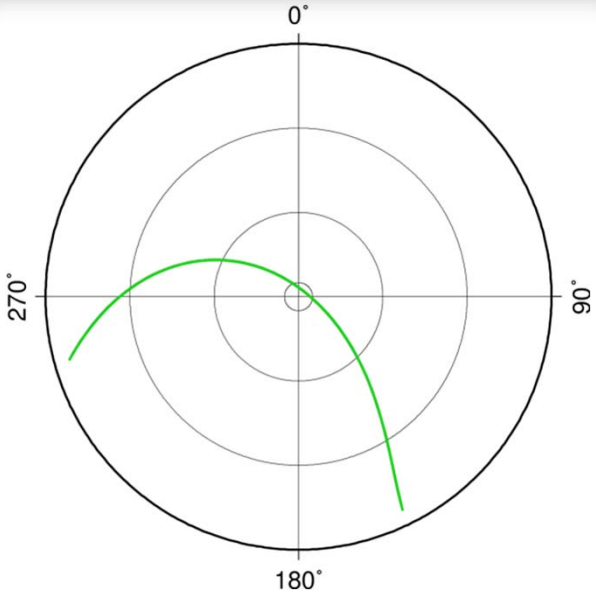


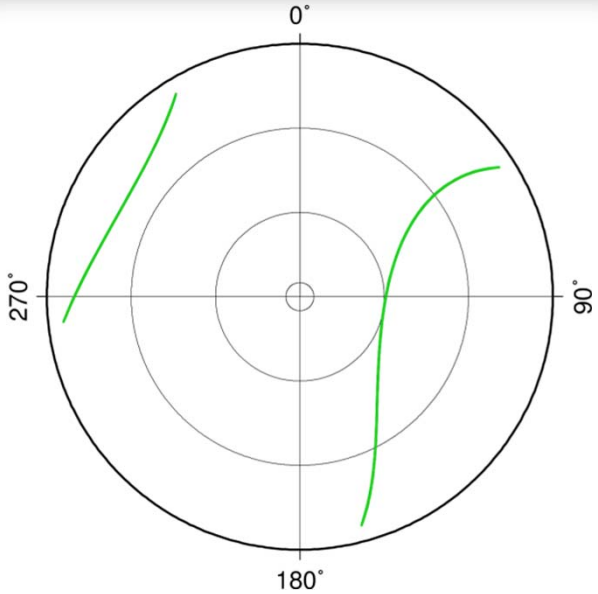
Malindi
(Kenya)
equator

Sky plots for G06 for 1 day (30-Mar-2012)

Satellite visibility: GPS

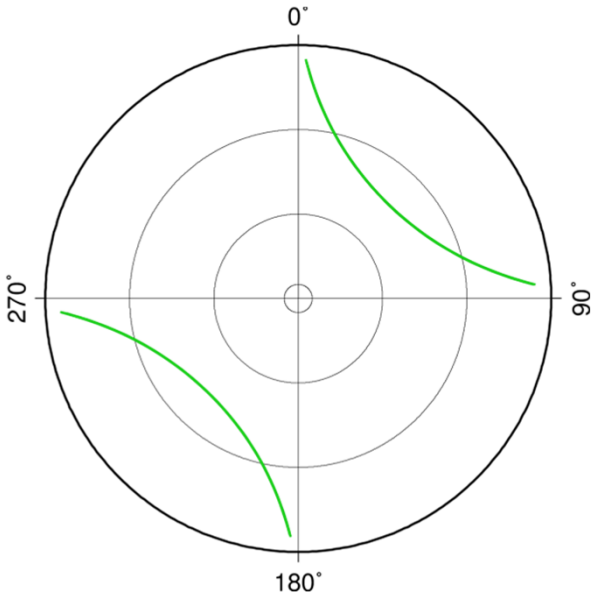
Zimmerwald
(Switzerland)
mid-latitude

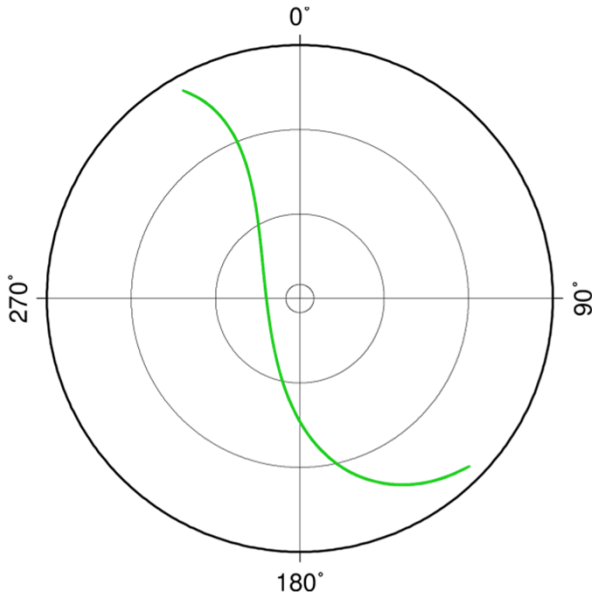




Algonquin
(Canada)
mid-latitude

Amundson-Scott
(South pole)
pole



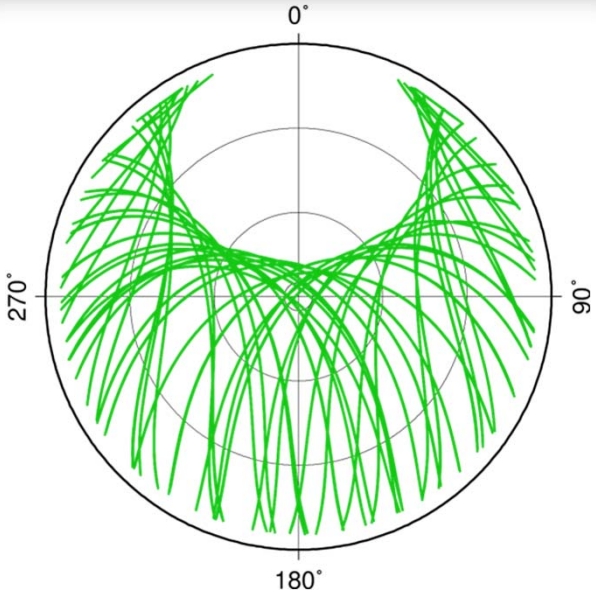


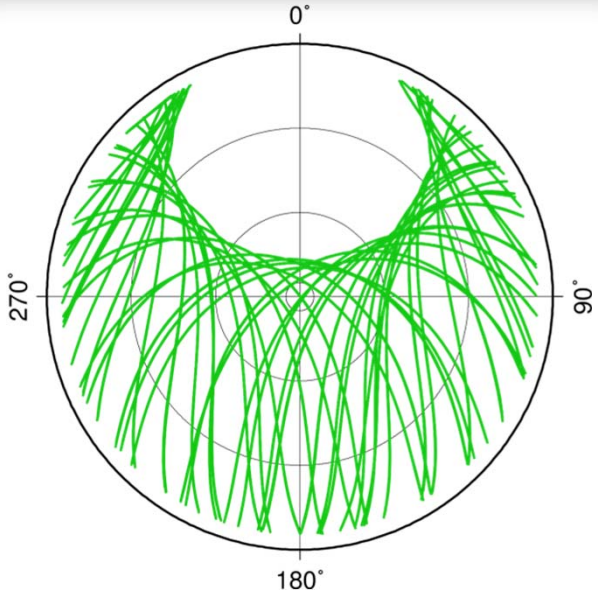
Malindi
(Kenya)
equator

Sky plots for G06 for 10 days (30-Mar-2012 to 08-Apr-2012)

Satellite visibility: GPS

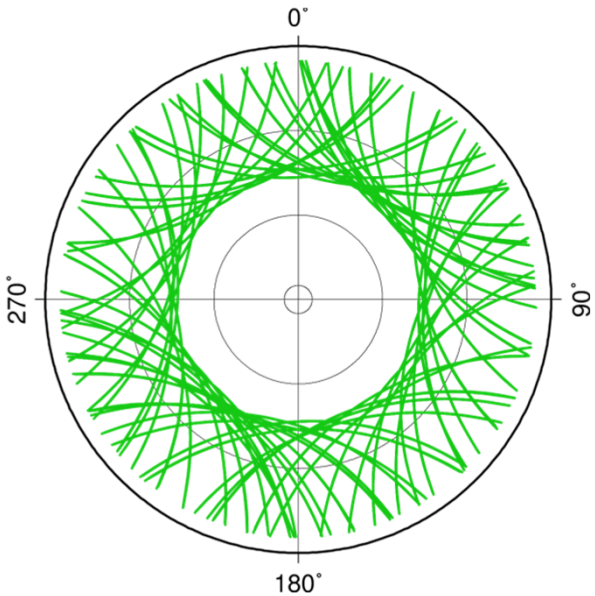
Zimmerwald
(Switzerland)
mid-latitude

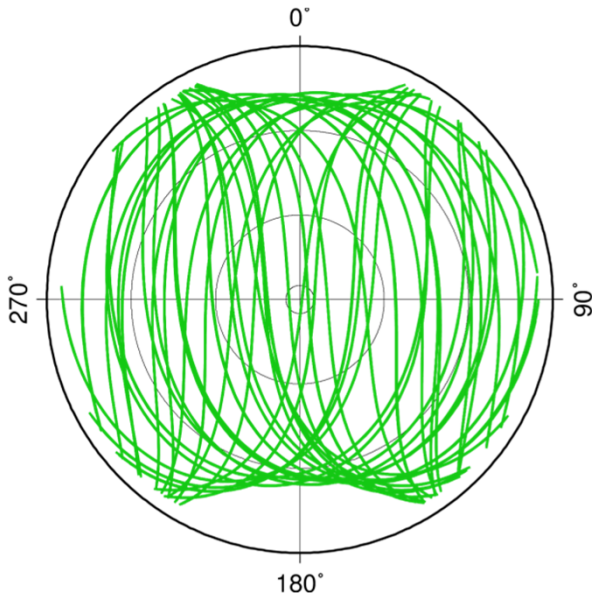




Algonquin
(Canada)
mid-latitude

Amundson-Scott
(South pole)
pole



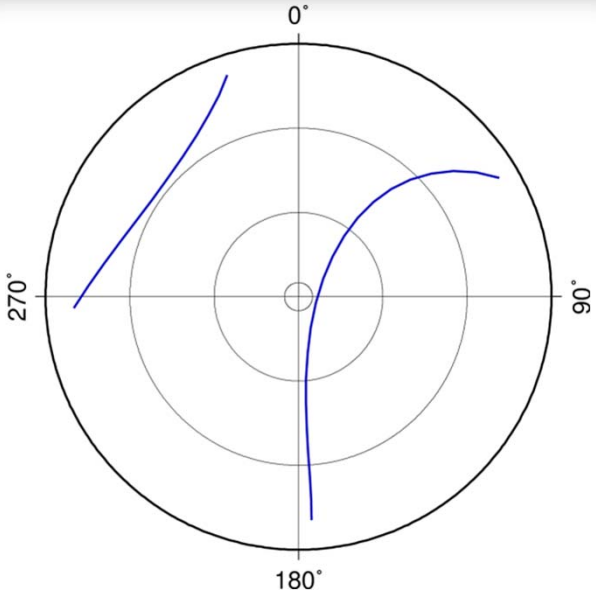


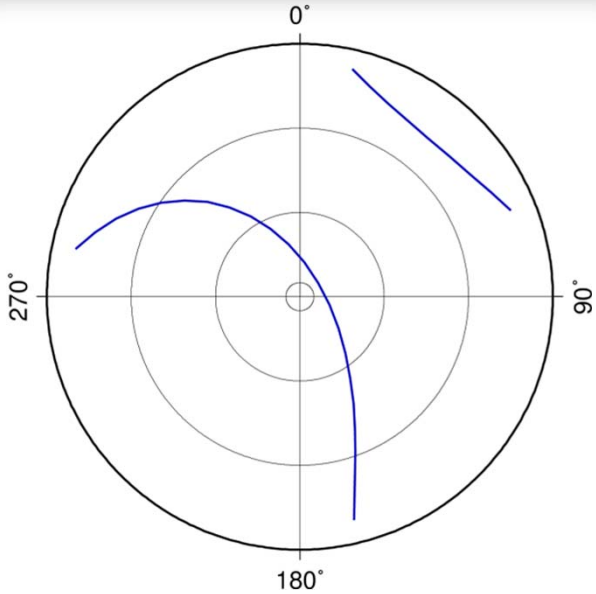
Malindi
(Kenya)
equator

Sky plots for all GPS satellites for 10 days (30-Mar-2012 to 08-Apr-2012)

Satellite visibility: GLONASS

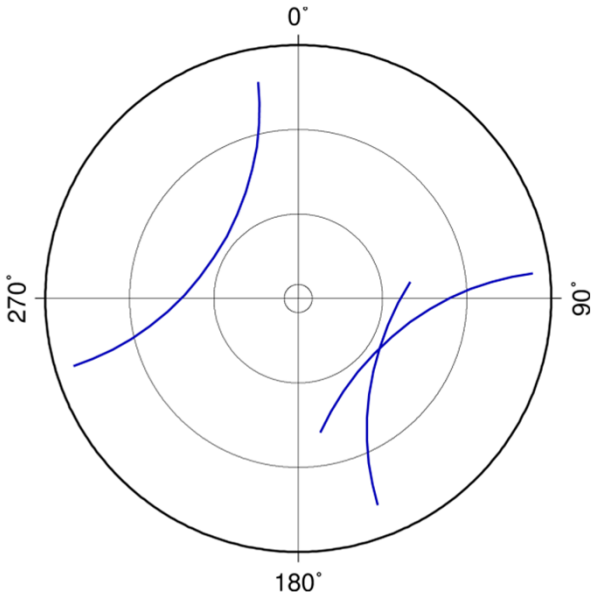
Zimmerwald
(Switzerland)
mid-latitude

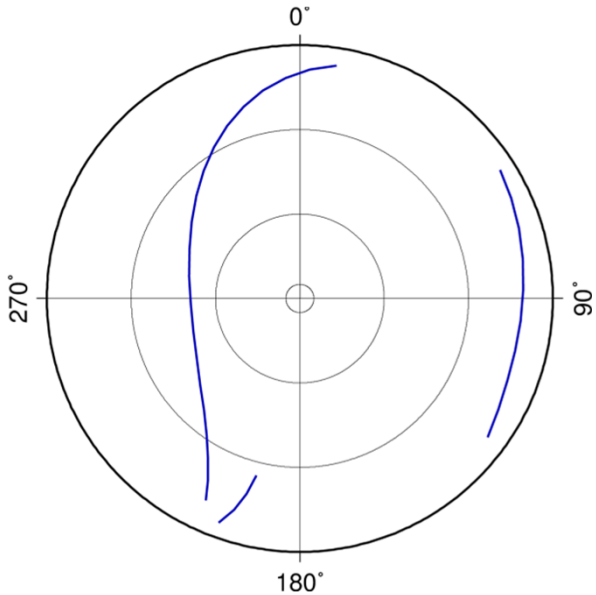




Algonquin
(Canada)
mid-latitude

Amundson-Scott
(South pole)
pole



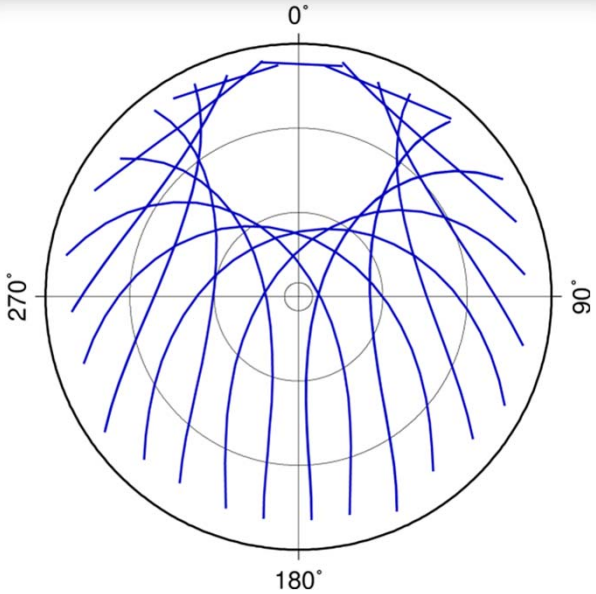


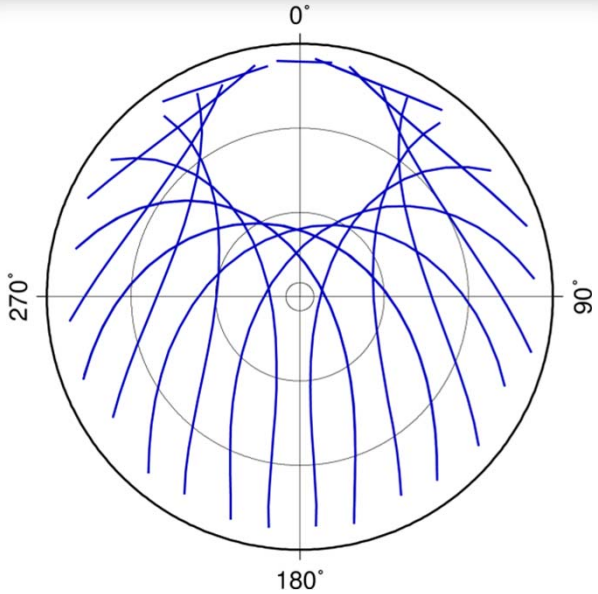
Malindi
(Kenya)
equator

Sky plots for R04 for 1 day (30-Mar-2012)

Satellite visibility: GLONASS

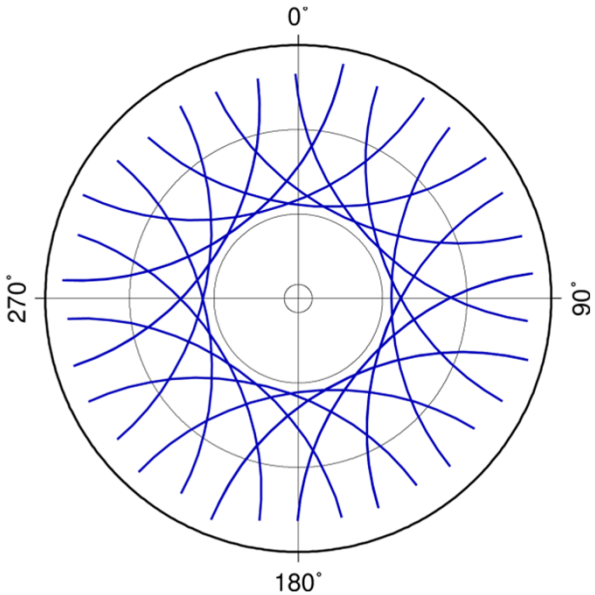
Zimmerwald
(Switzerland)
mid-latitude

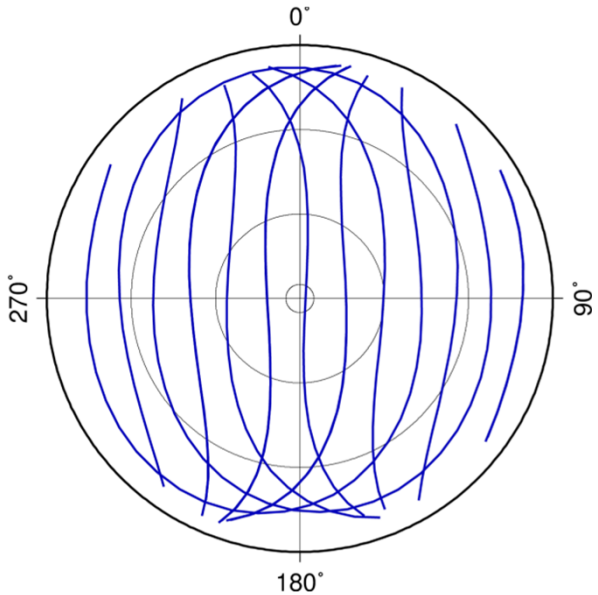




Algonquin
(Canada)
mid-latitude

Amundson-Scott
(South pole)
pole



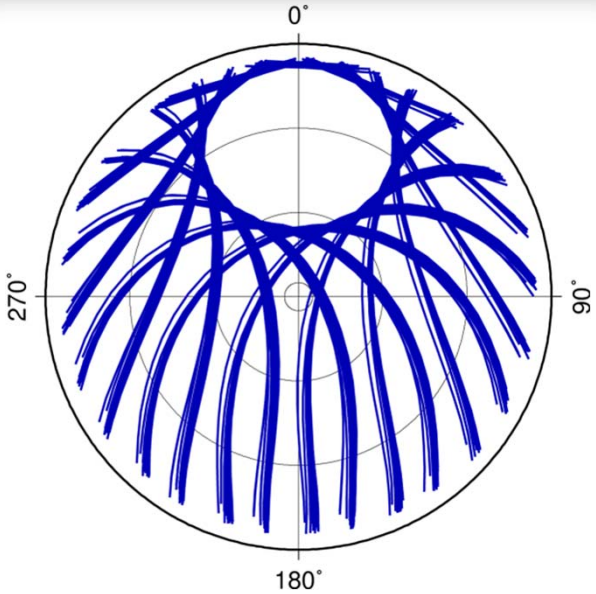


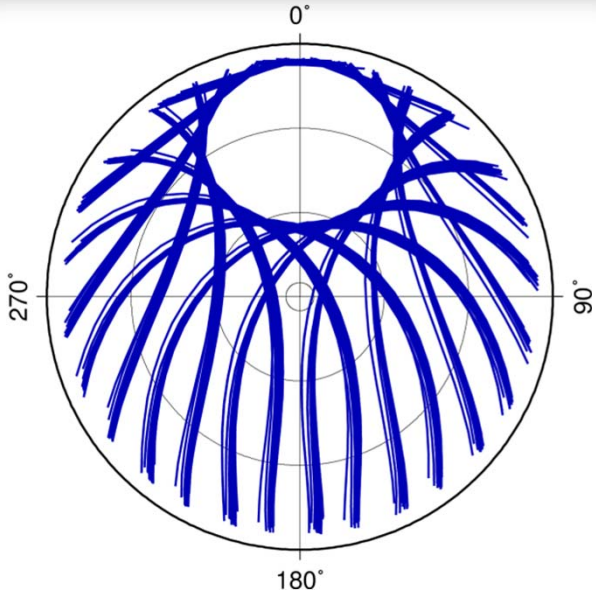
Malindi
(Kenya)
equator

Sky plots for R04 for 10 days (30-Mar-2012 to 08-Apr-2012)

Satellite visibility: GLONASS

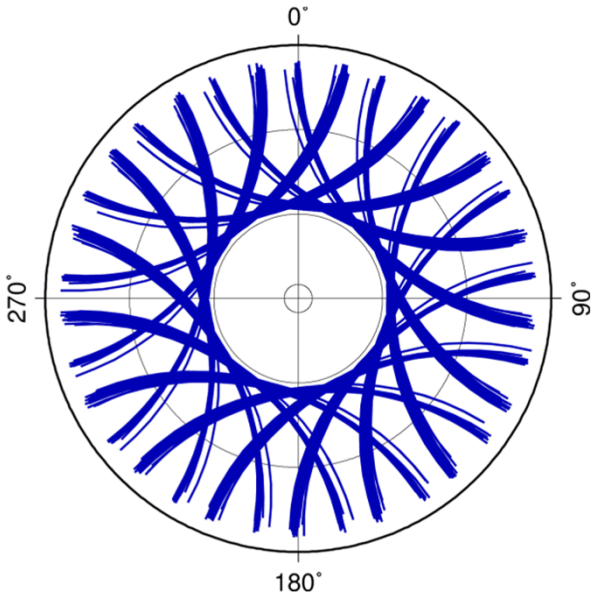
Zimmerwald
(Switzerland)
mid-latitude

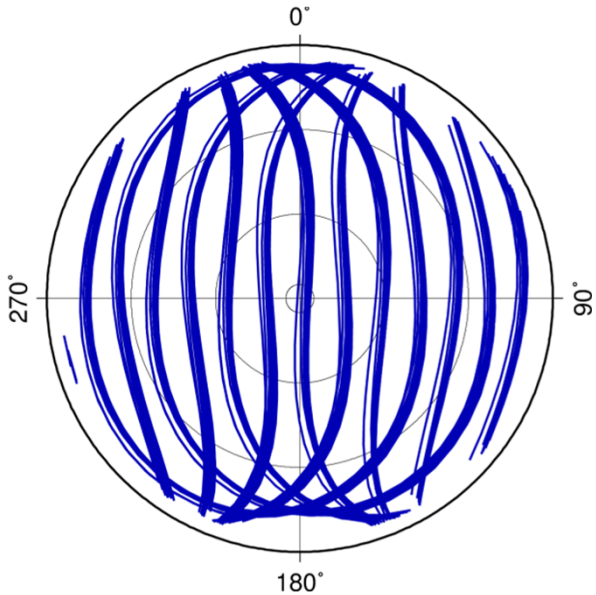




Algonquin
(Canada)
mid-latitude

Amundson-Scott
(South pole)
pole



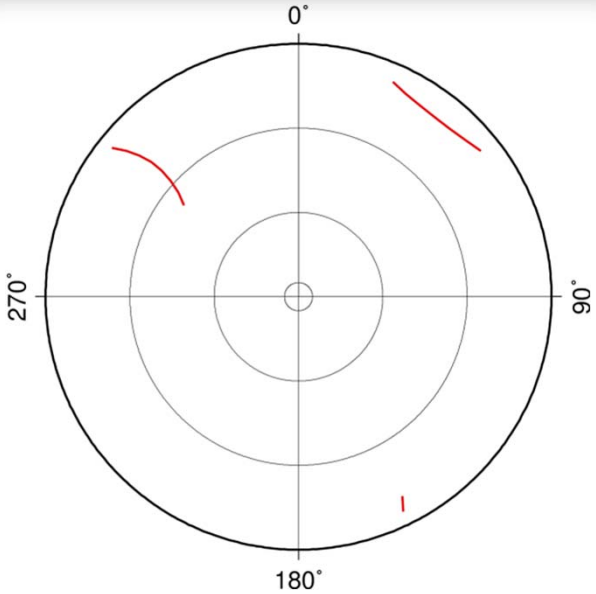


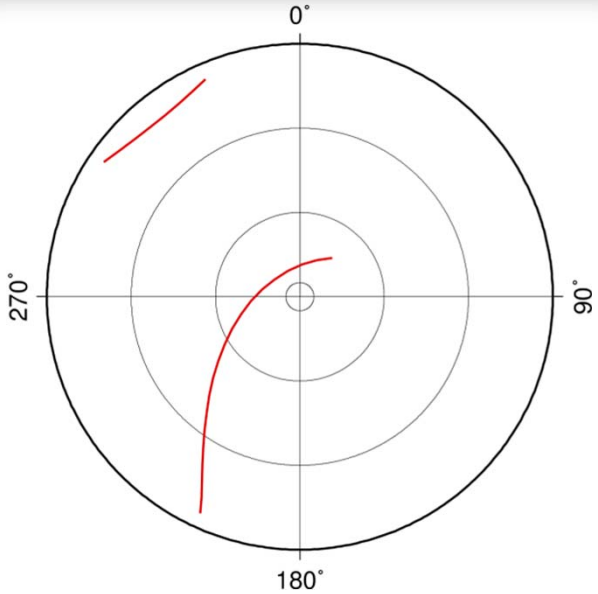
Malindi
(Kenya)
equator

Sky plots for all GLONASS satellites for 10 days (30-Mar-2012 to 08-Apr-2012)

Satellite visibility: Galileo

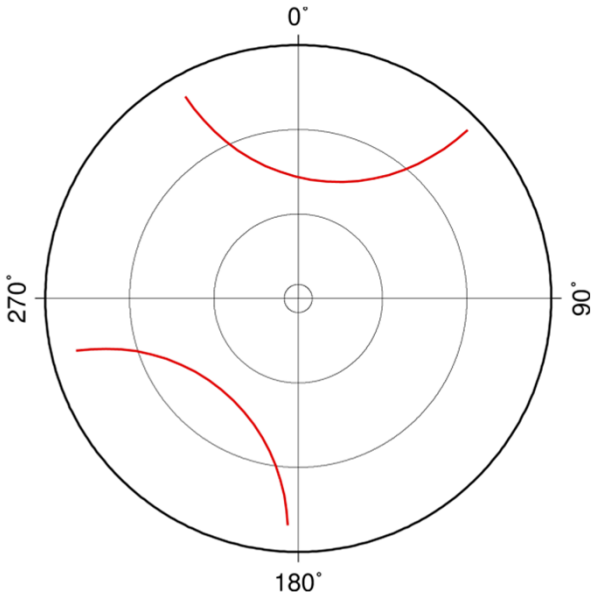
Zimmerwald
(Switzerland)
mid-latitude

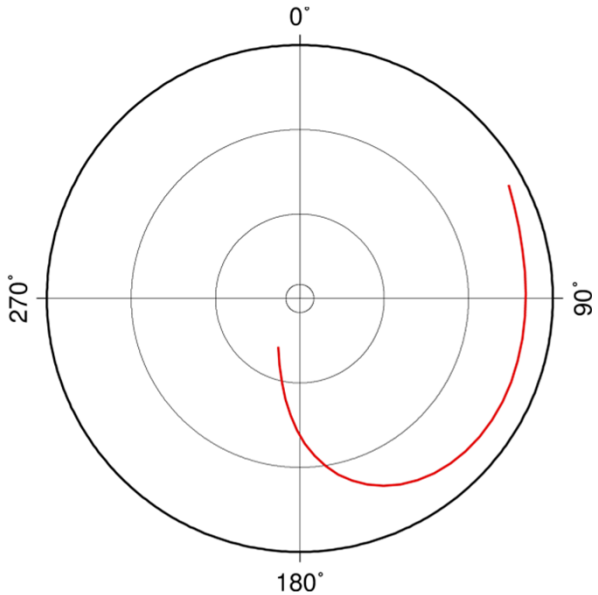




Algonquin
(Canada)
mid-latitude

Amundson-Scott
(South pole)
pole



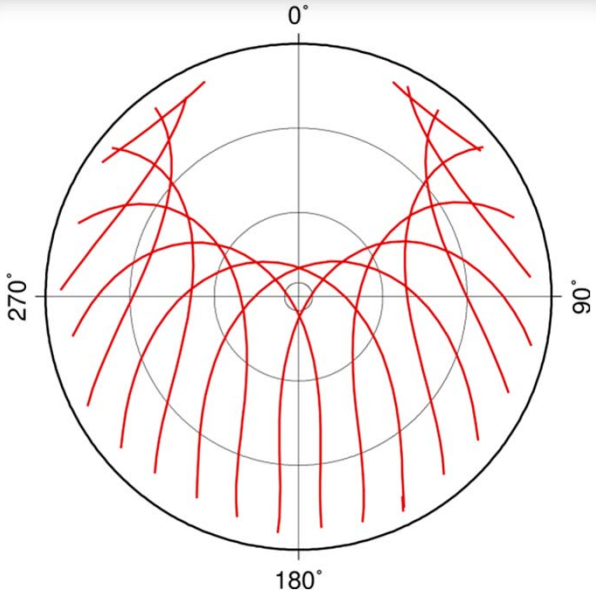


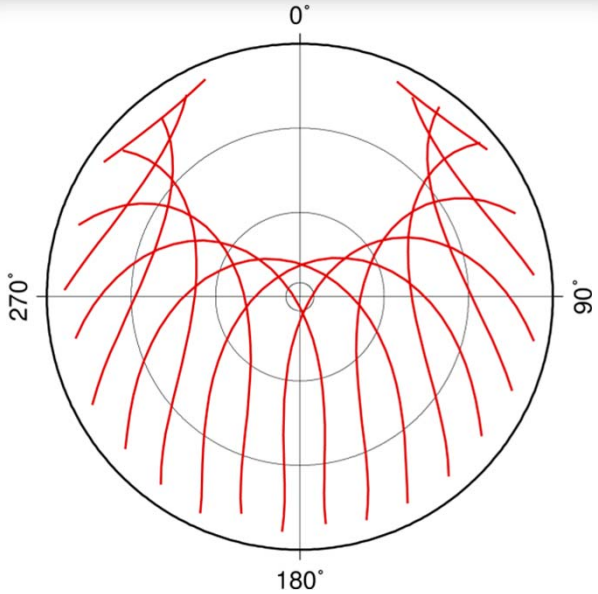
Malindi
(Kenya)
equator

Sky plots for E06 for 1 day (fictive constellation)

Satellite visibility: Galileo

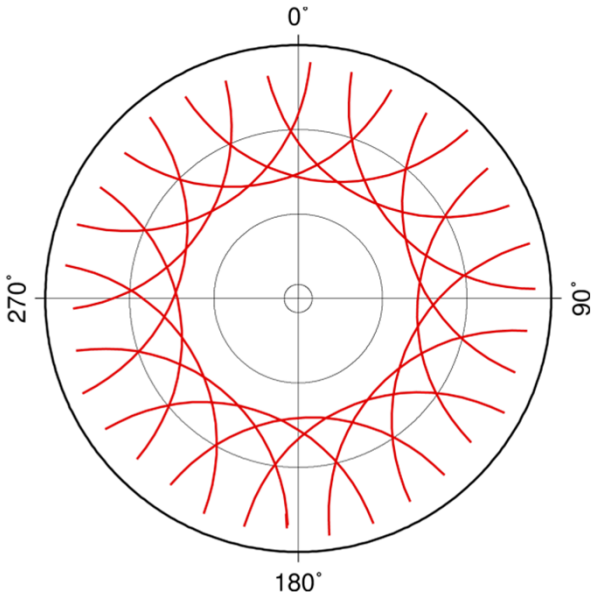
Zimmerwald
(Switzerland)
mid-latitude

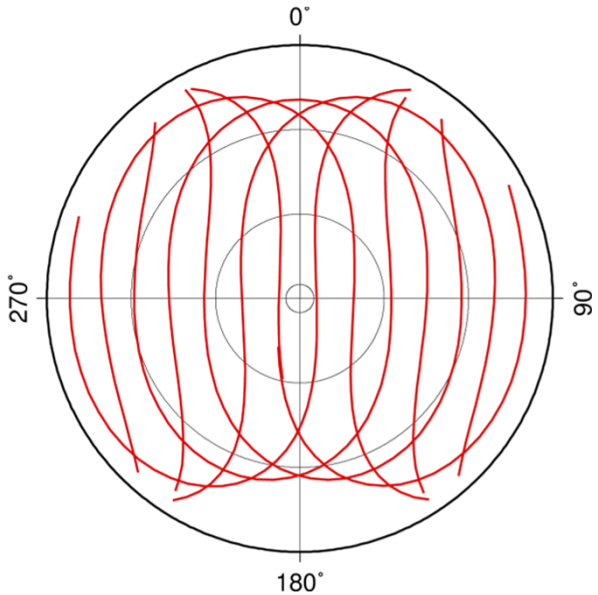




Algonquin
(Canada)
mid-latitude

Amundson-Scott
(South pole)
pole



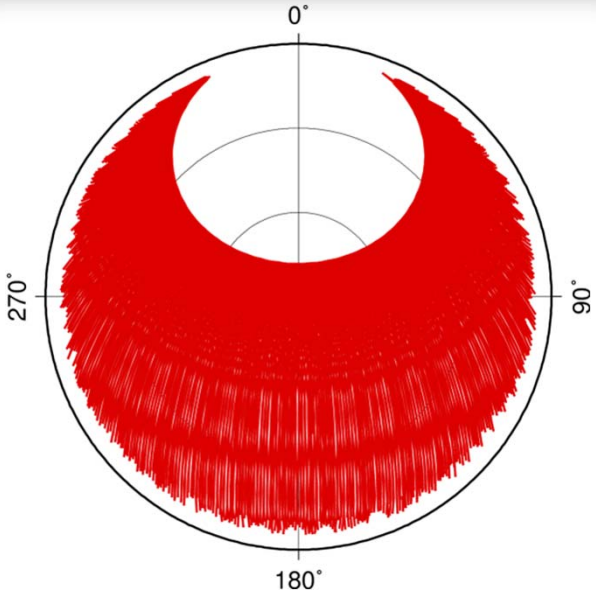


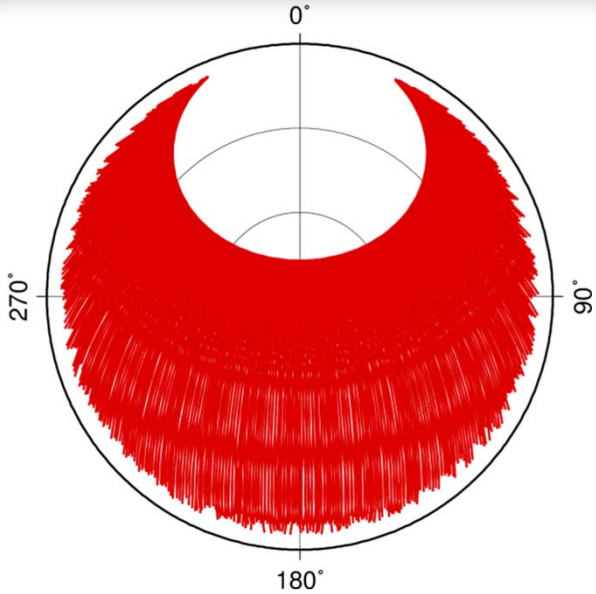
Malindi
(Kenya)
equator

Sky plots for E06 for 10 days (fictive constellation)

Satellite visibility: Galileo

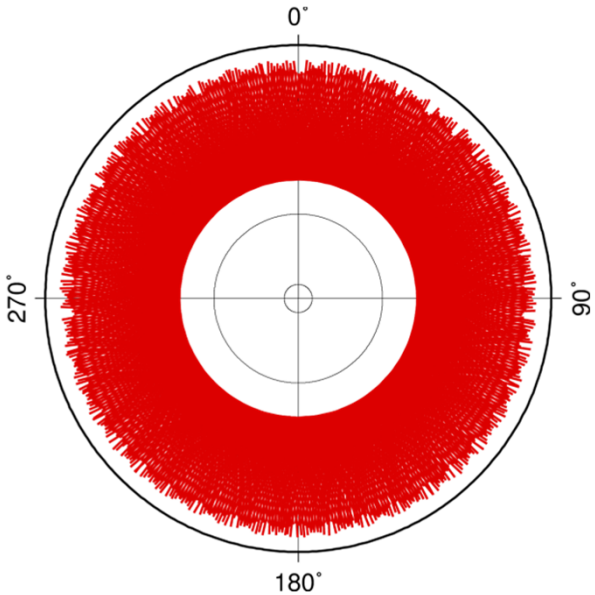
Zimmerwald
(Switzerland)
mid-latitude

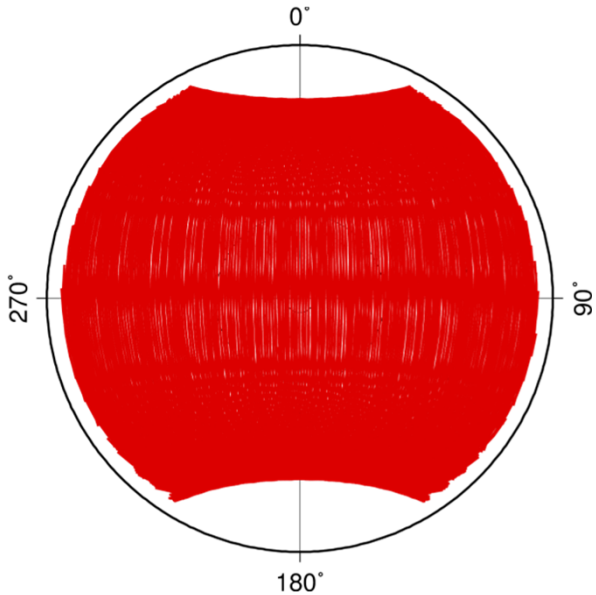




Algonquin
(Canada)
mid-latitude

Amundson-Scott
(South pole)
pole





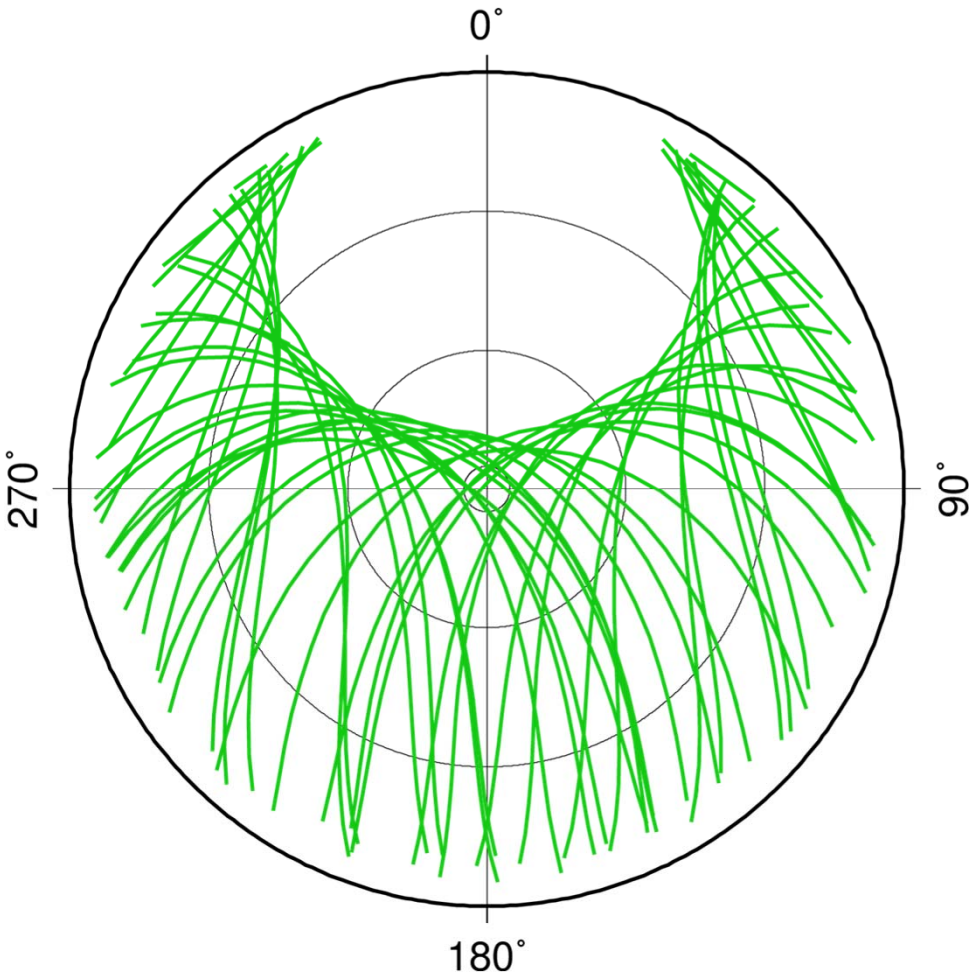
Malindi
(Kenya)
equator

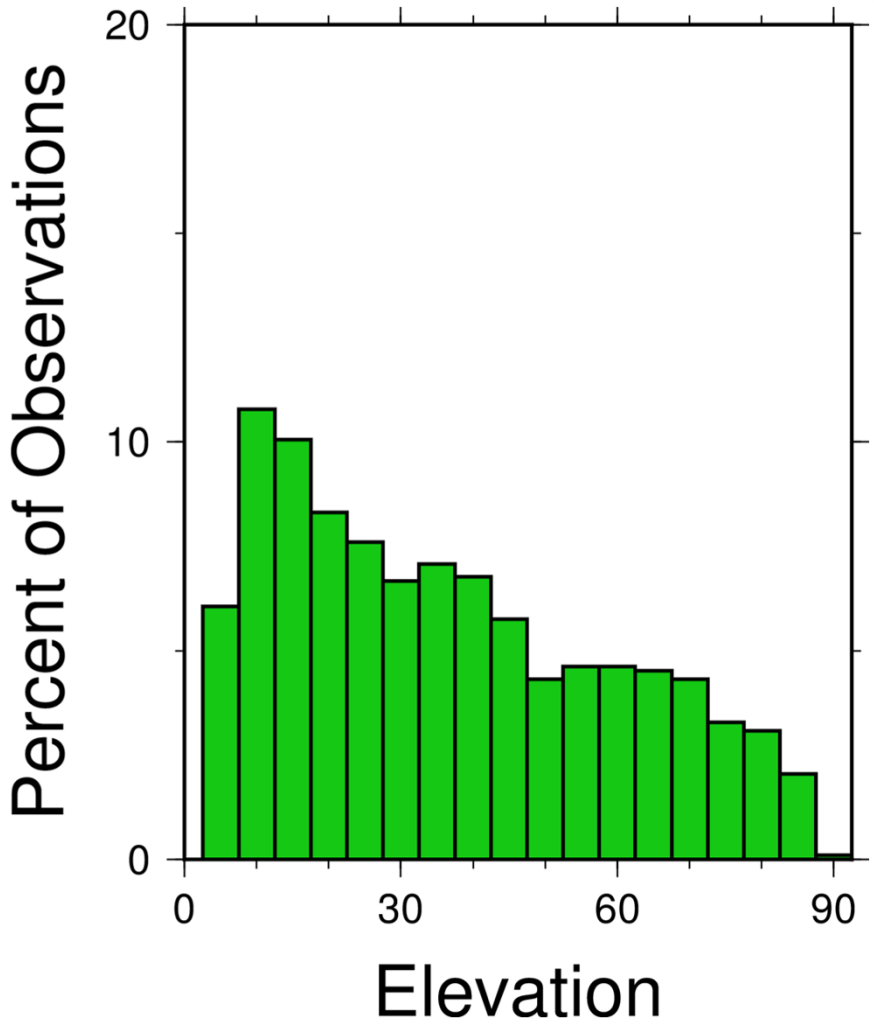
Sky plots for all Galileo satellites for 10 days (fictive constellation)

Histogram for elevation and azimuth

Zimmerwald, Switzerland

mid-latitude



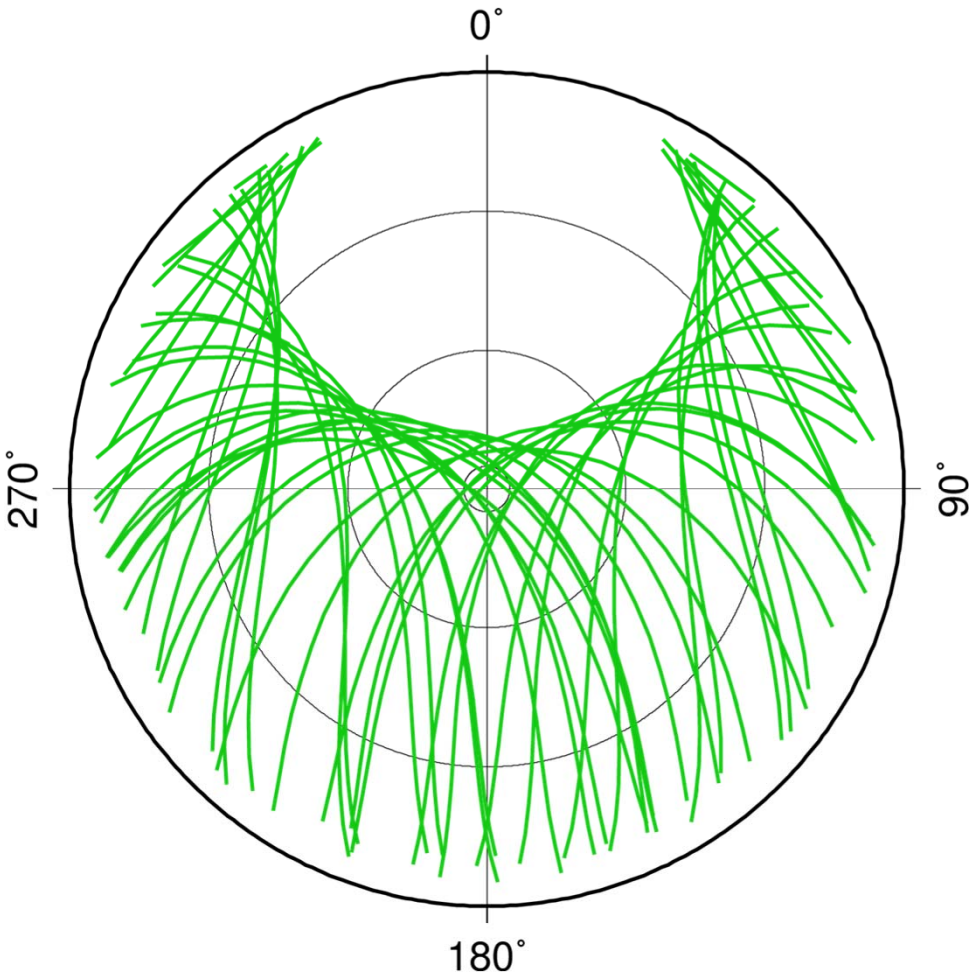


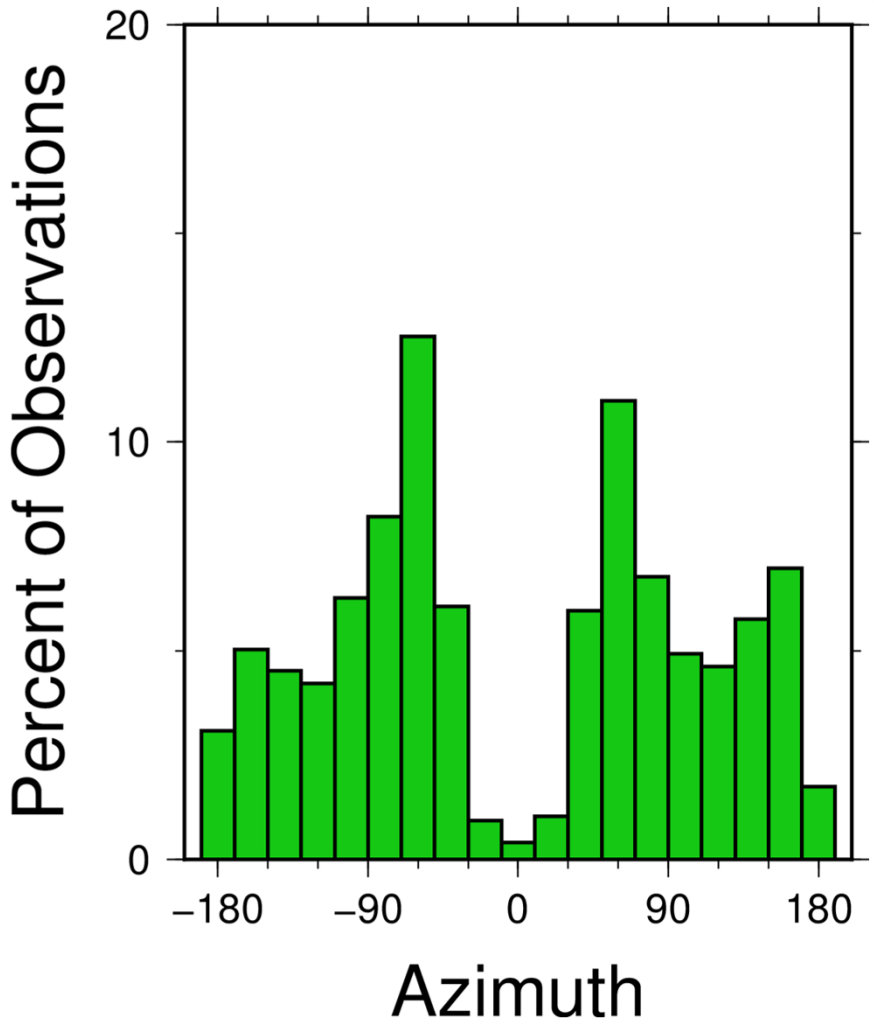
Sky plot for all GPS satellites for 1 day (30-Mar-2012)

Histogram for elevation and azimuth

Zimmerwald, Switzerland

mid-latitude

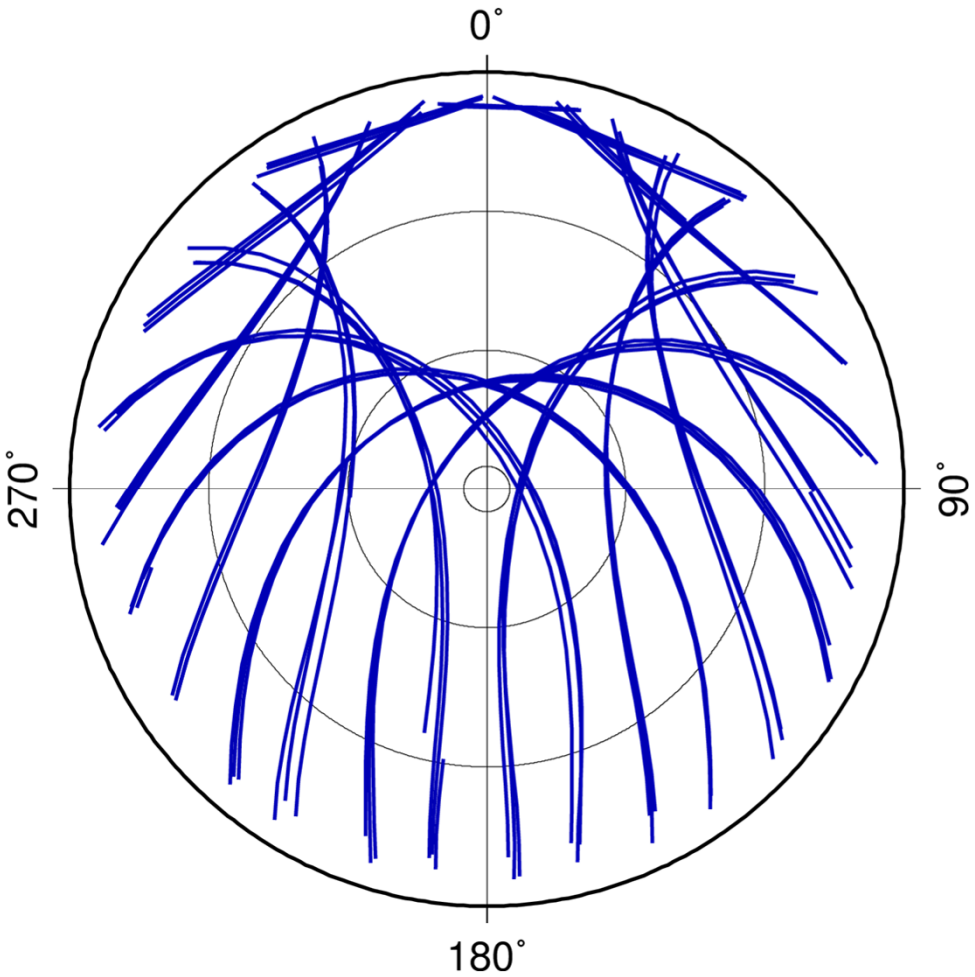


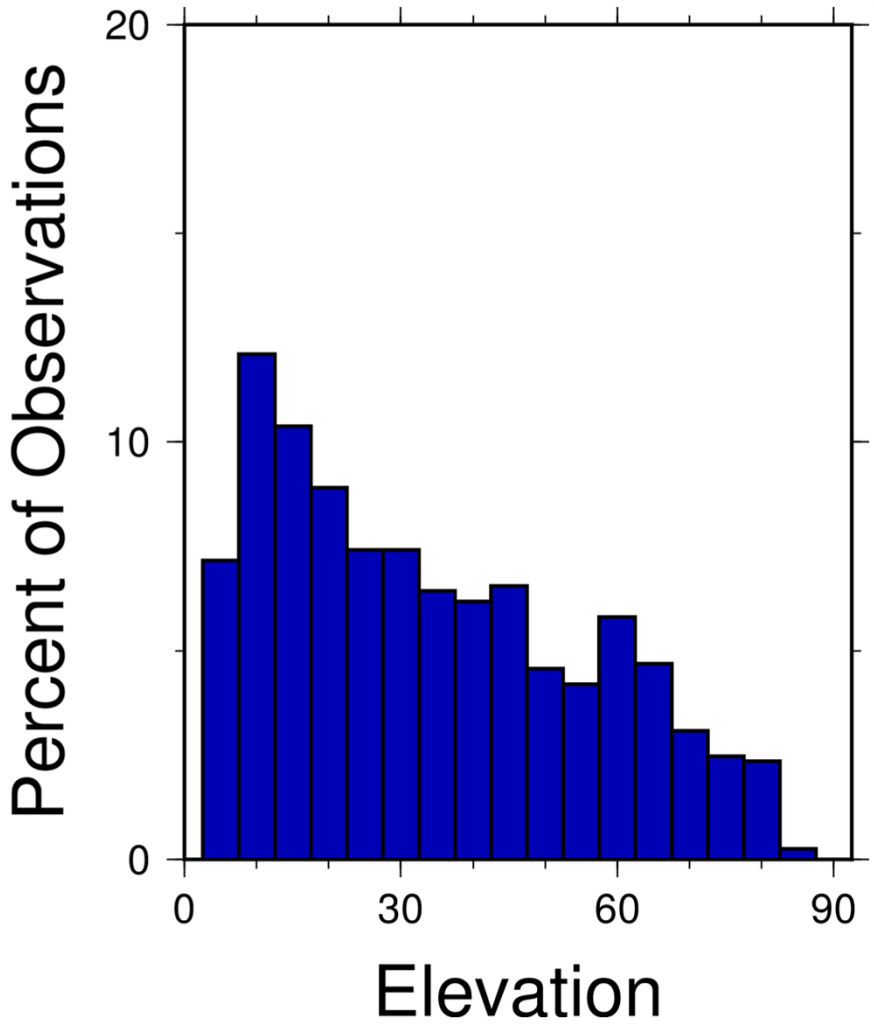


Sky plot for all GPS satellites for 1 day (30-Mar-2012)

Histogram for elevation and azimuth

Zimmerwald, Switzerland
mid-latitude



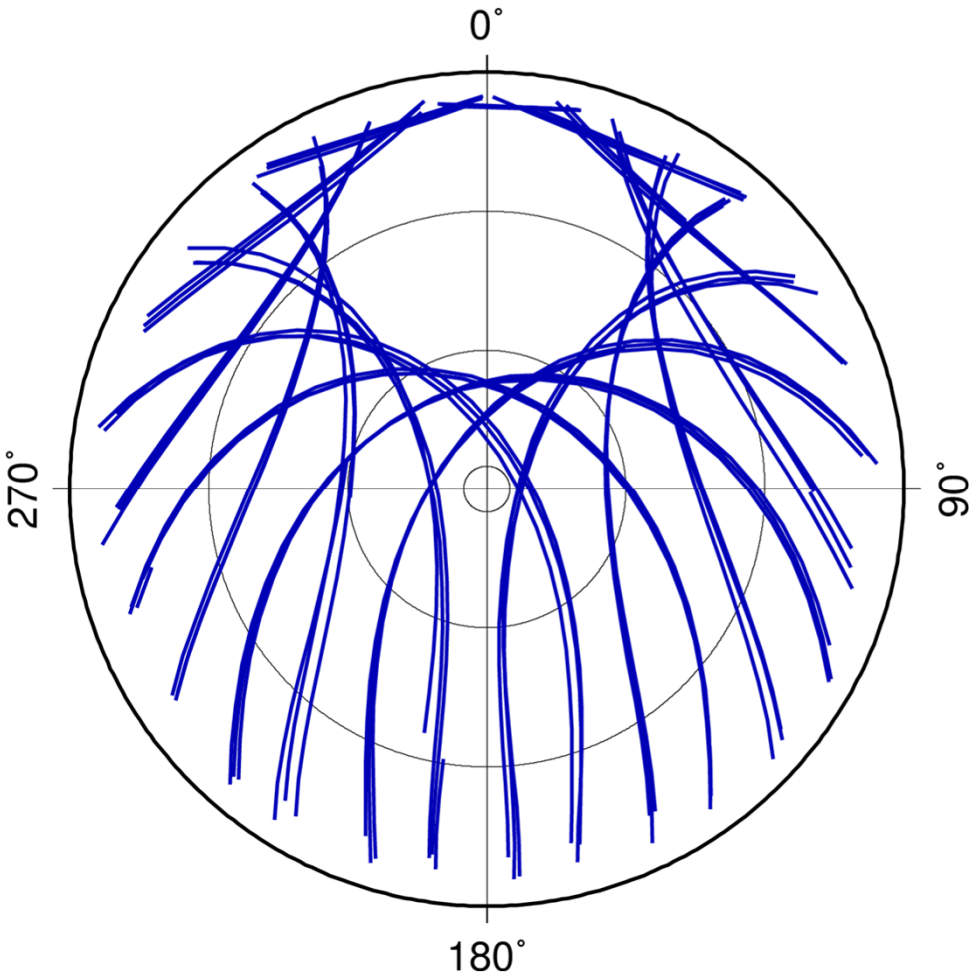


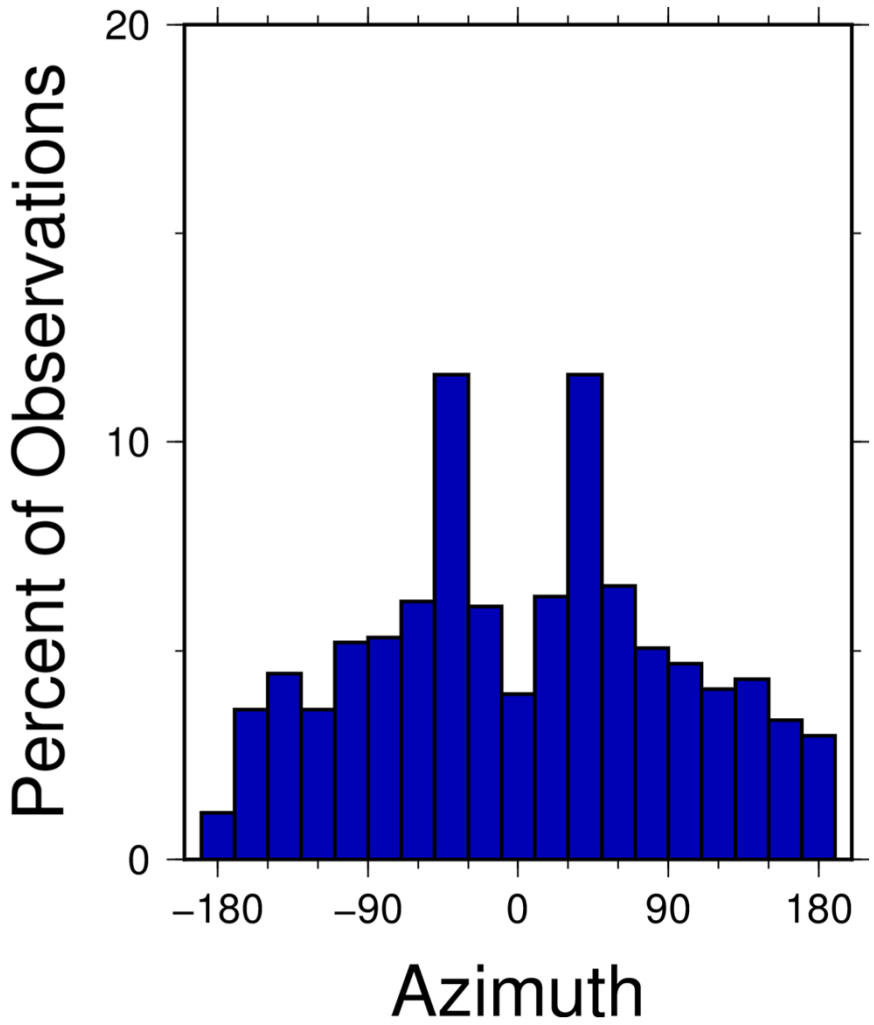
Sky plot for all GLONASS satellites for 1 day (30-Mar-2012)

Histogram for elevation and azimuth

Zimmerwald, Switzerland

mid-latitude

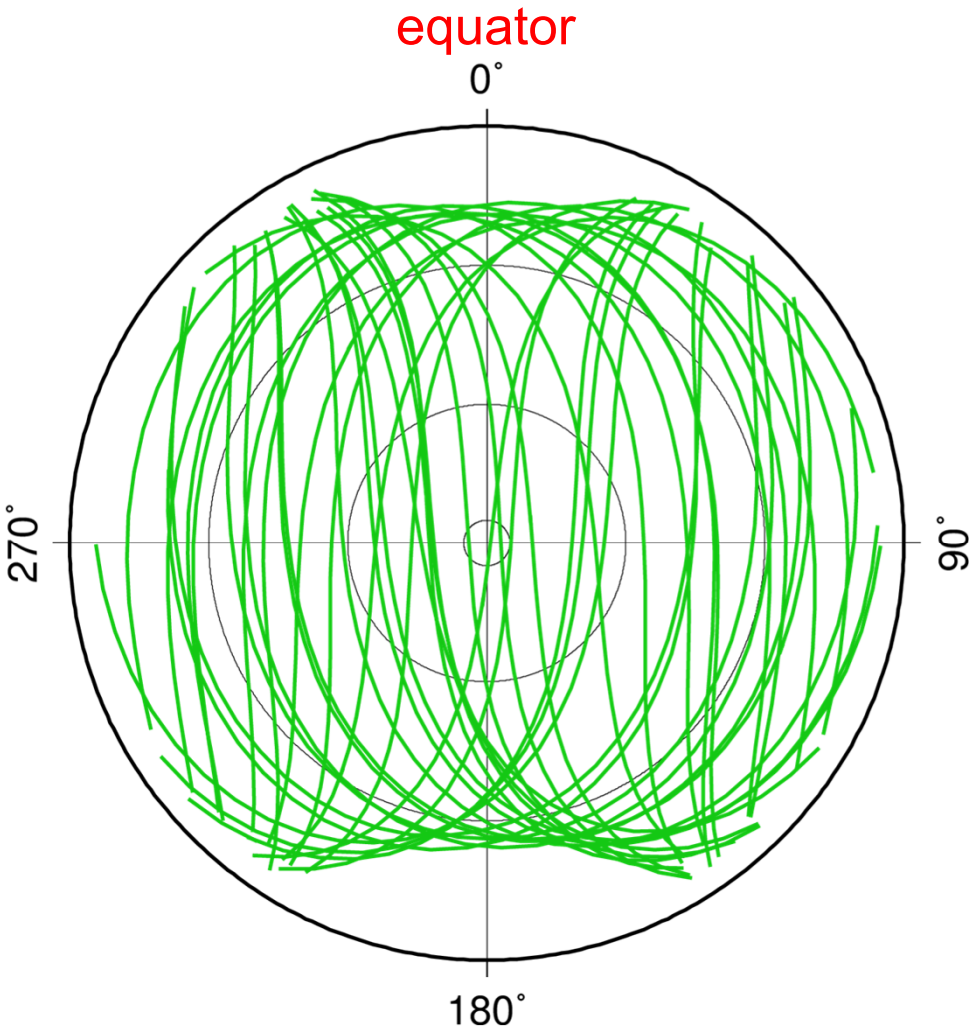


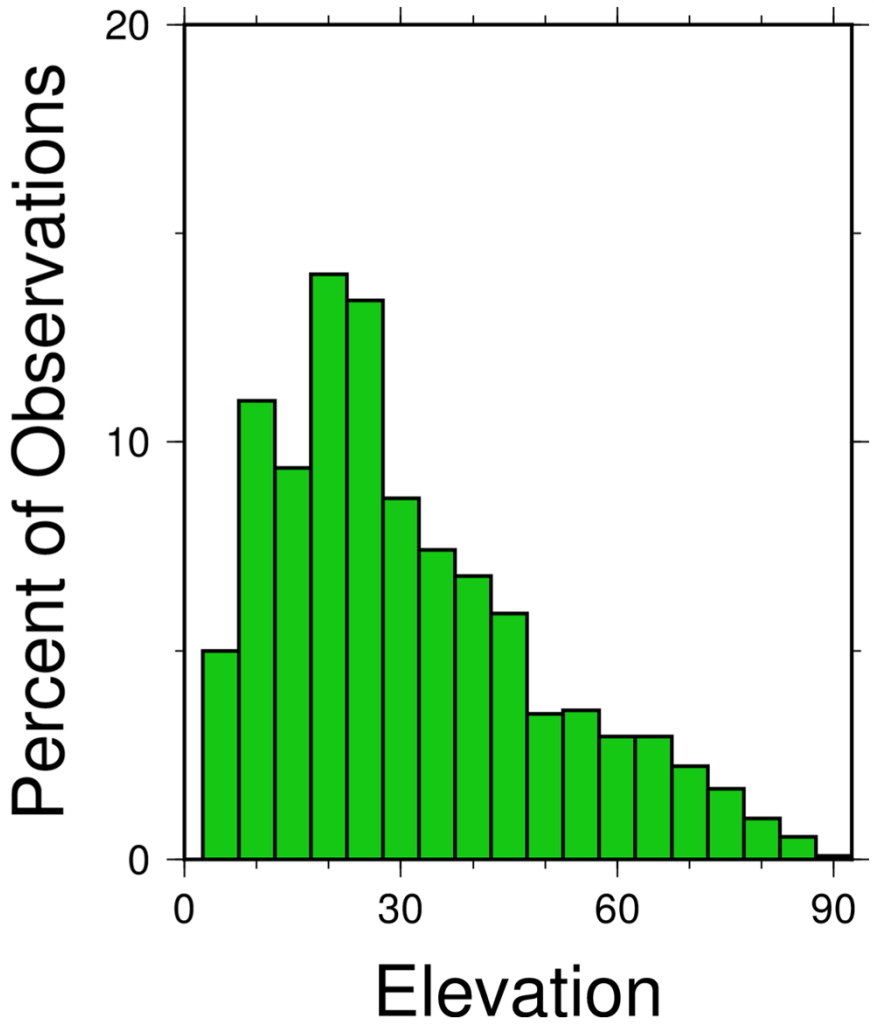


Sky plot for all GLONASS satellites for 1 day (30-Mar-2012)

Histogram for elevation and azimuth

Malindi, Kenya

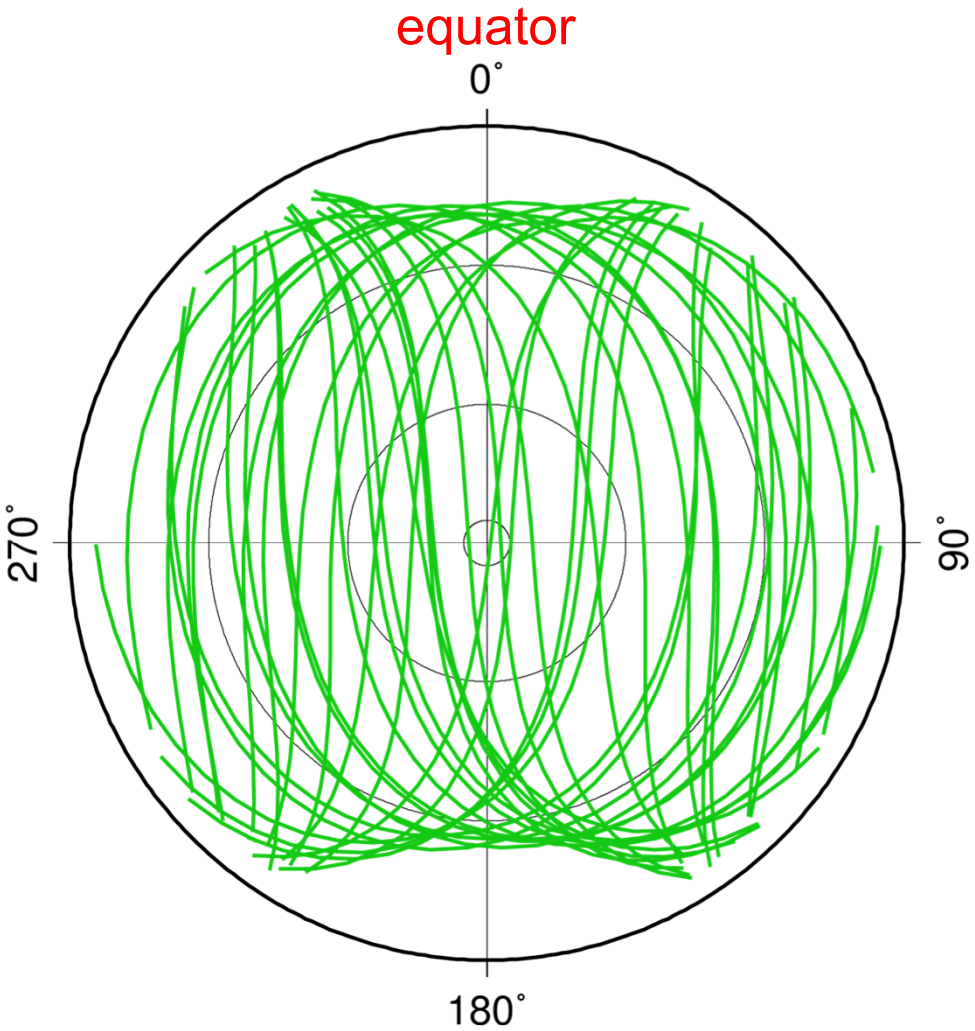


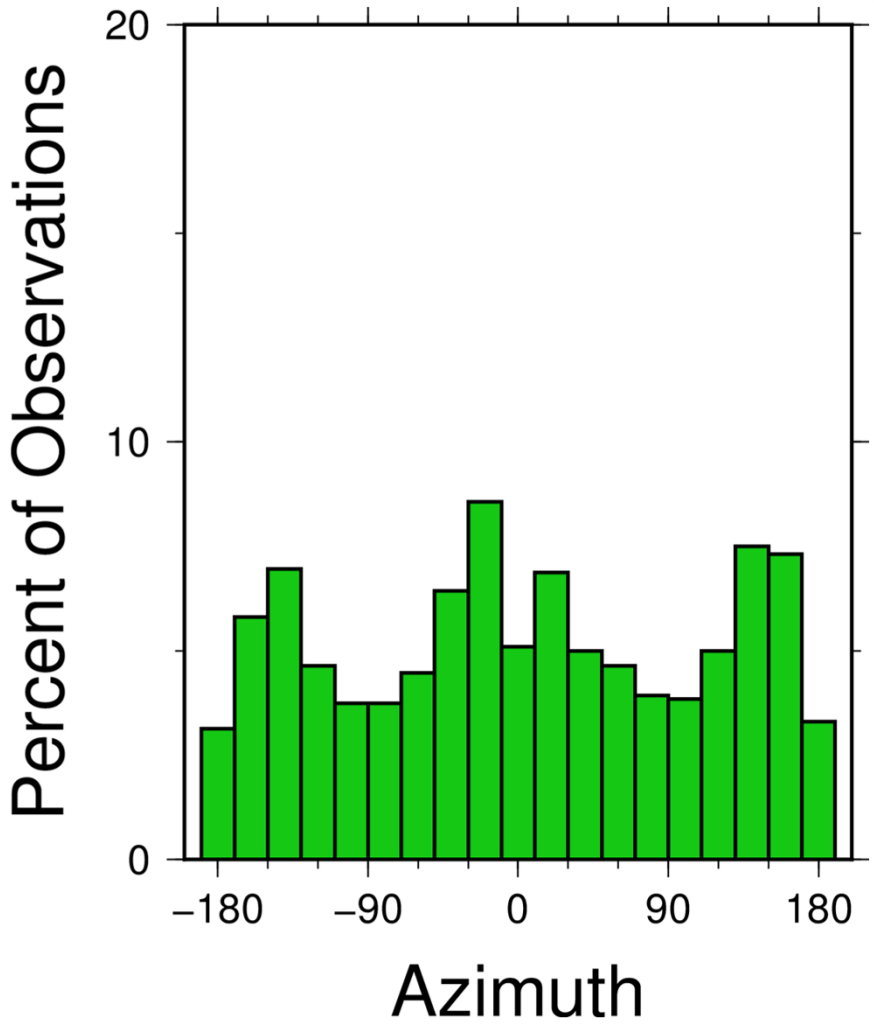


Sky plot for all GPS satellites for 1 day (30-Mar-2012)

Histogram for elevation and azimuth

Malindi, Kenya

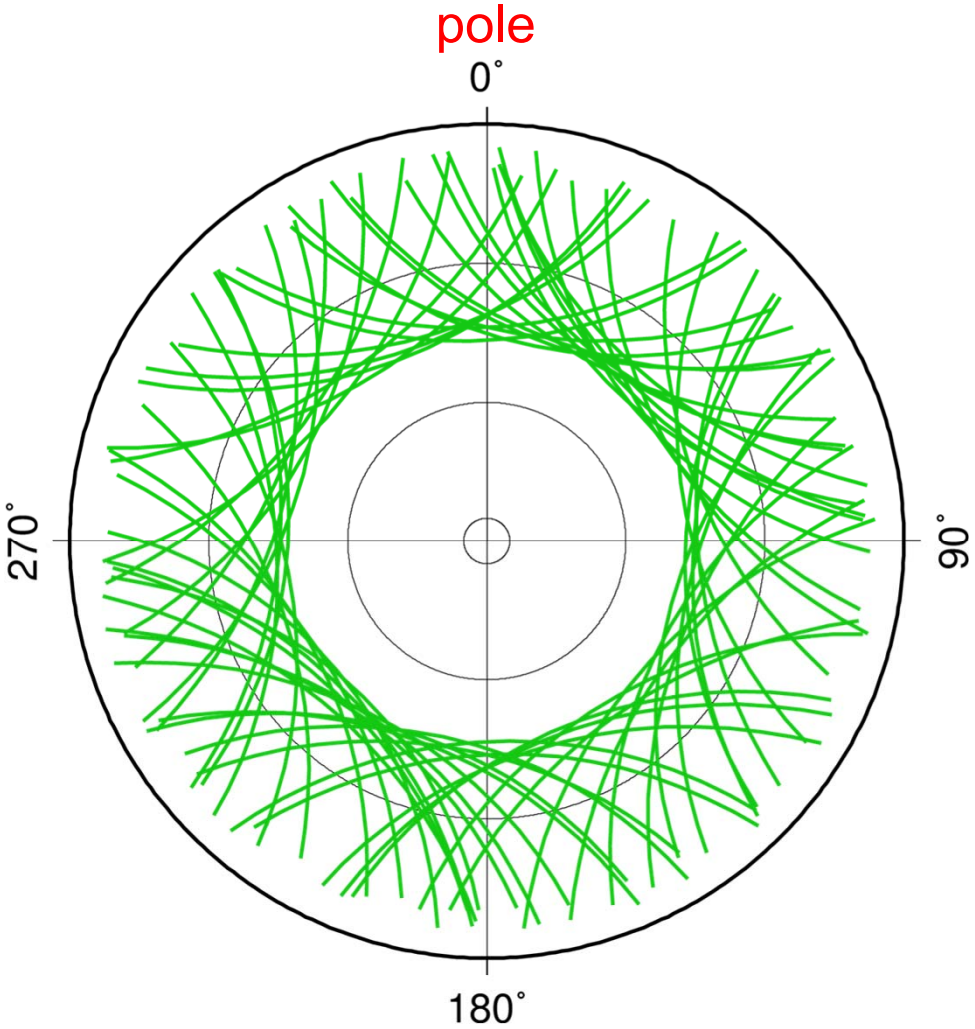


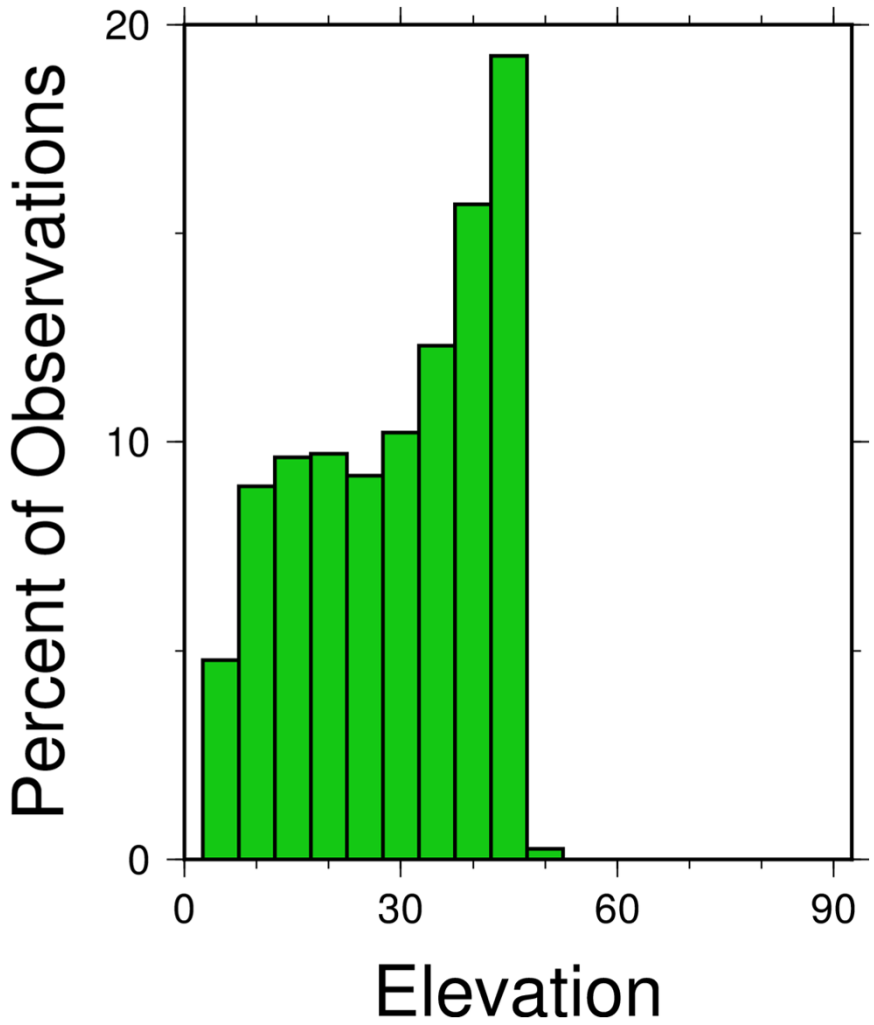


Sky plot for all GPS satellites for 1 day (30-Mar-2012)

Histogram for elevation and azimuth

Amundson-Scott, South pole

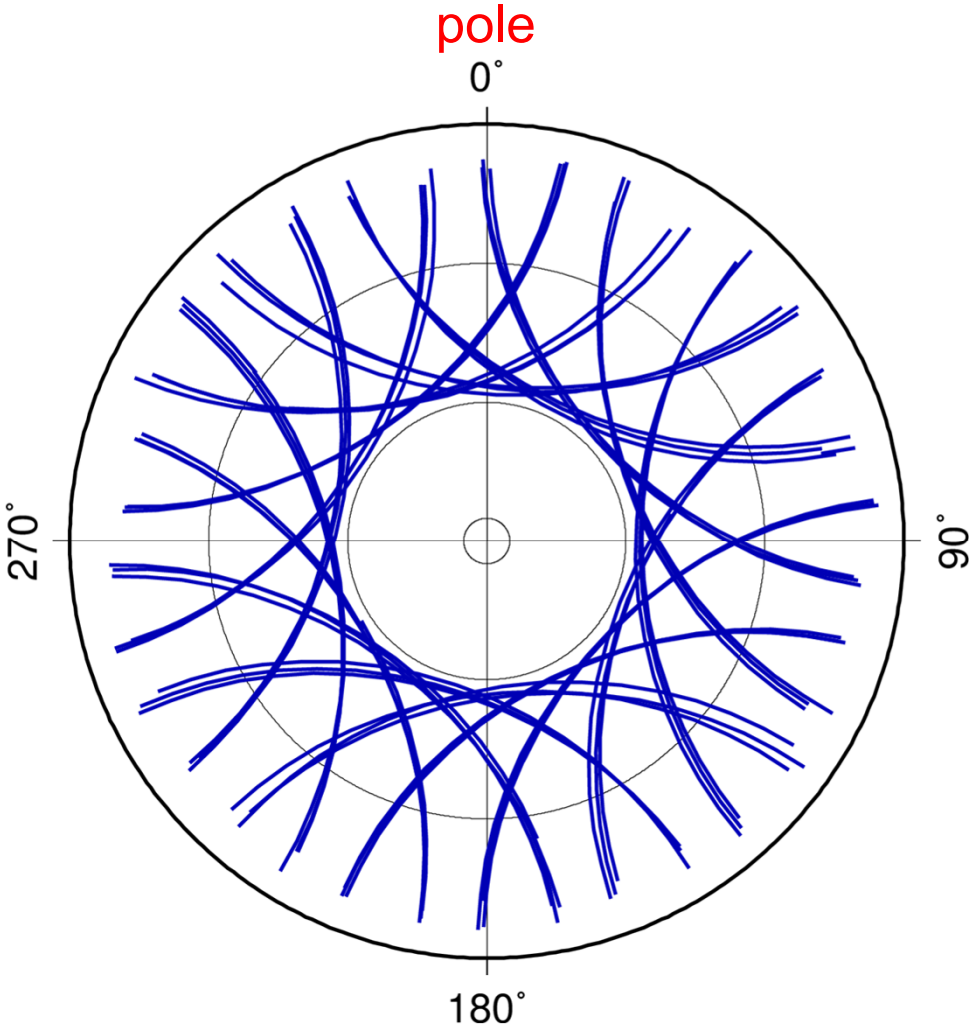


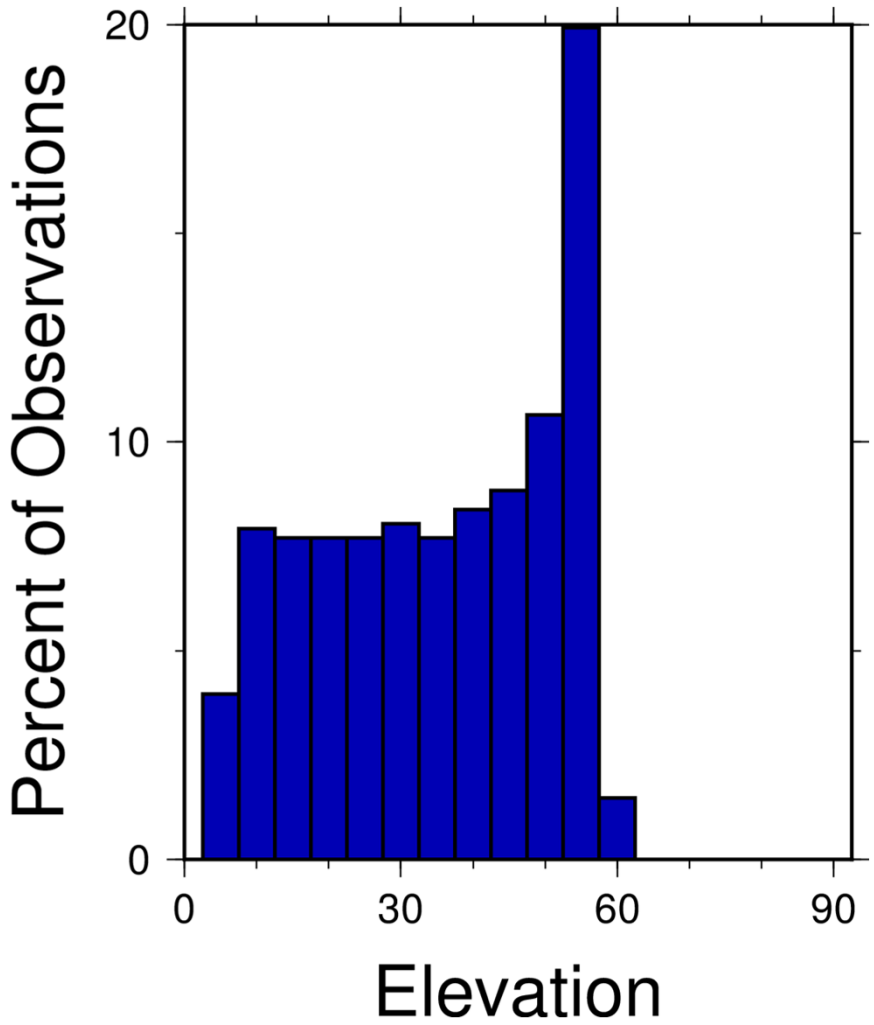


Sky plot for all GPS satellites for 1 day (30-Mar-2012)

Histogram for elevation and azimuth

Amundson-Scott, South pole

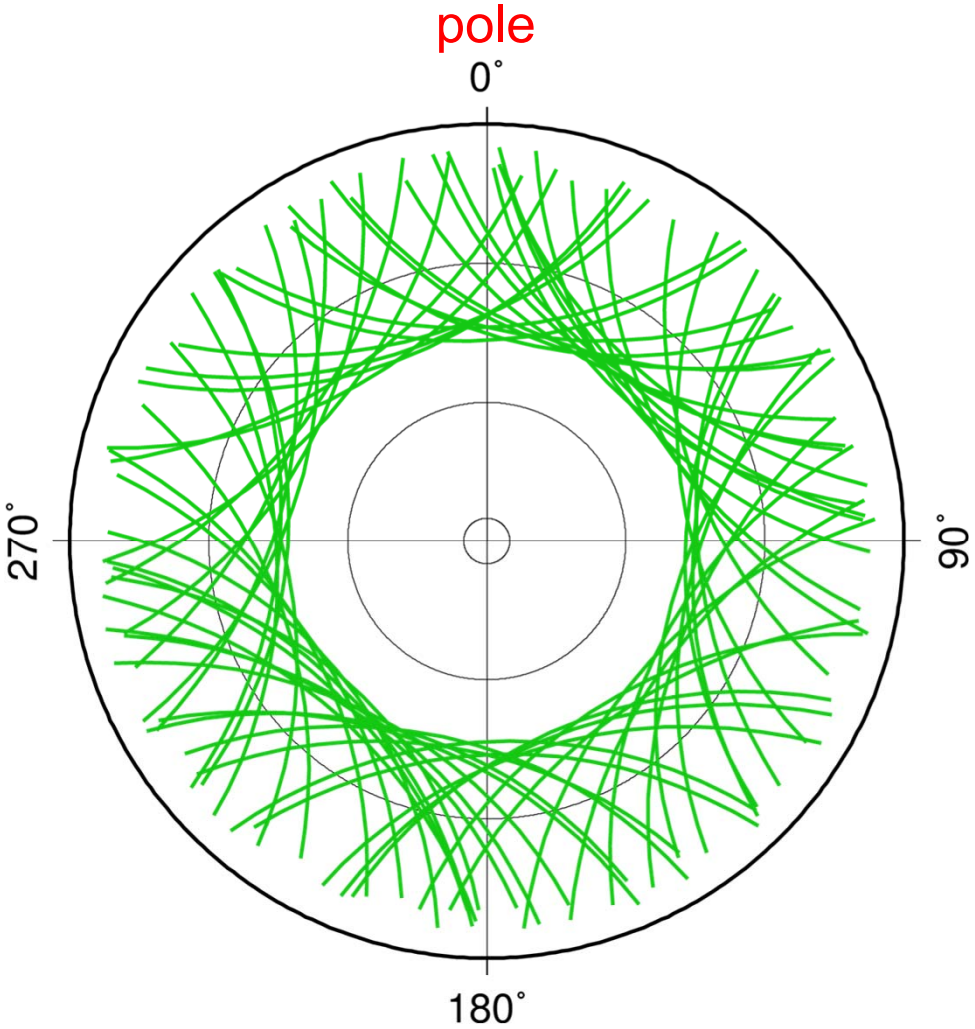


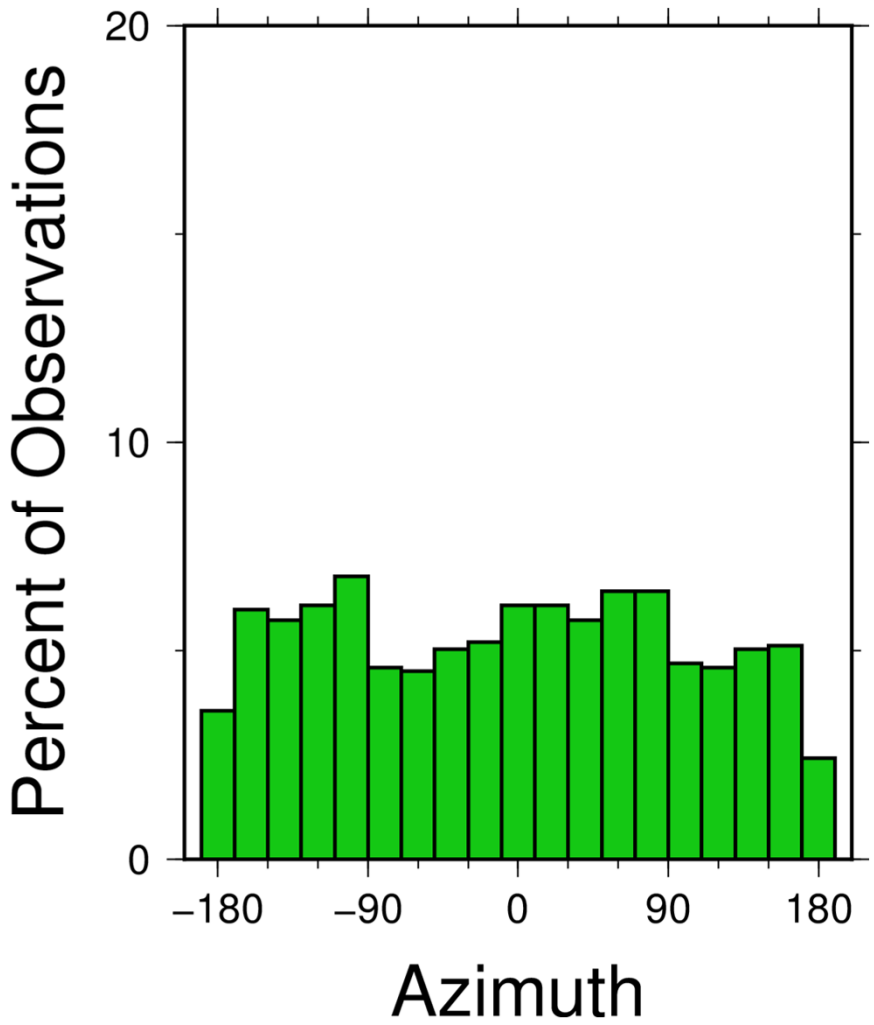


Sky plot for all GLONASS satellites for 1 day (30-Mar-2012)

Histogram for elevation and azimuth

Amundson-Scott, South pole

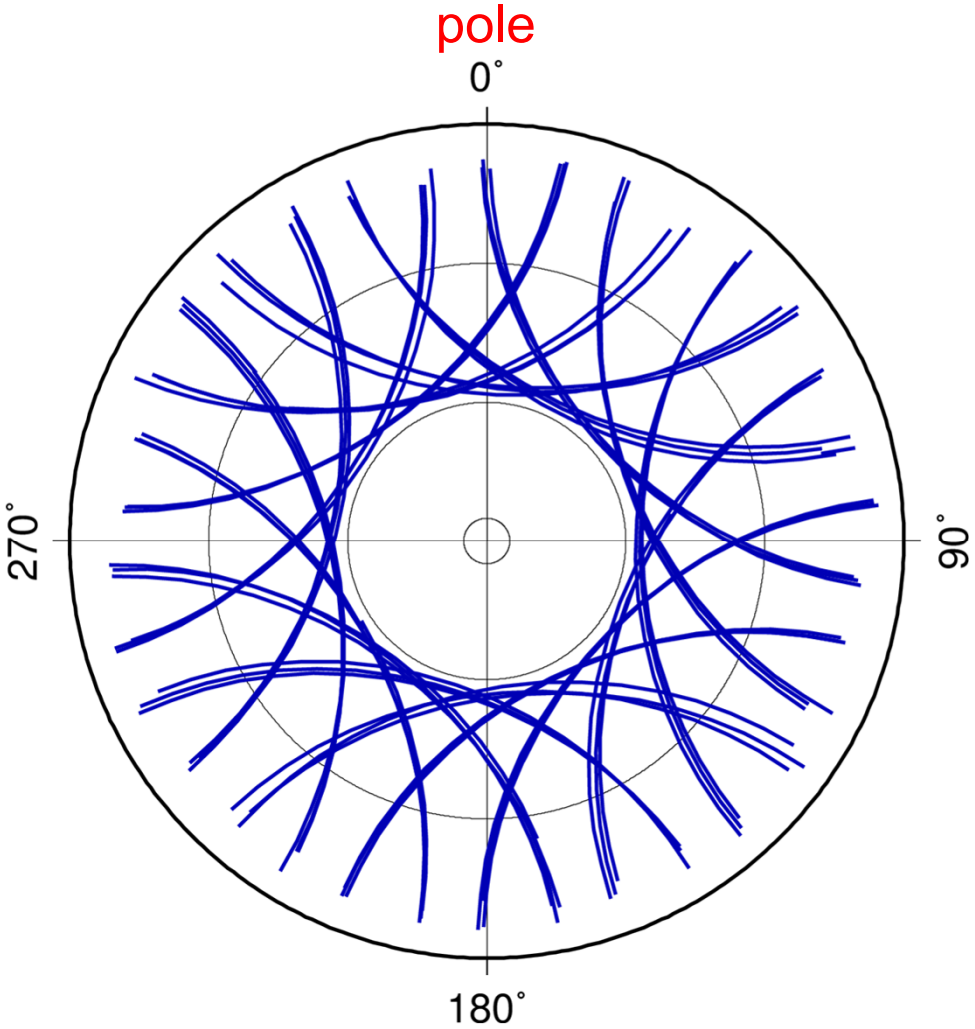


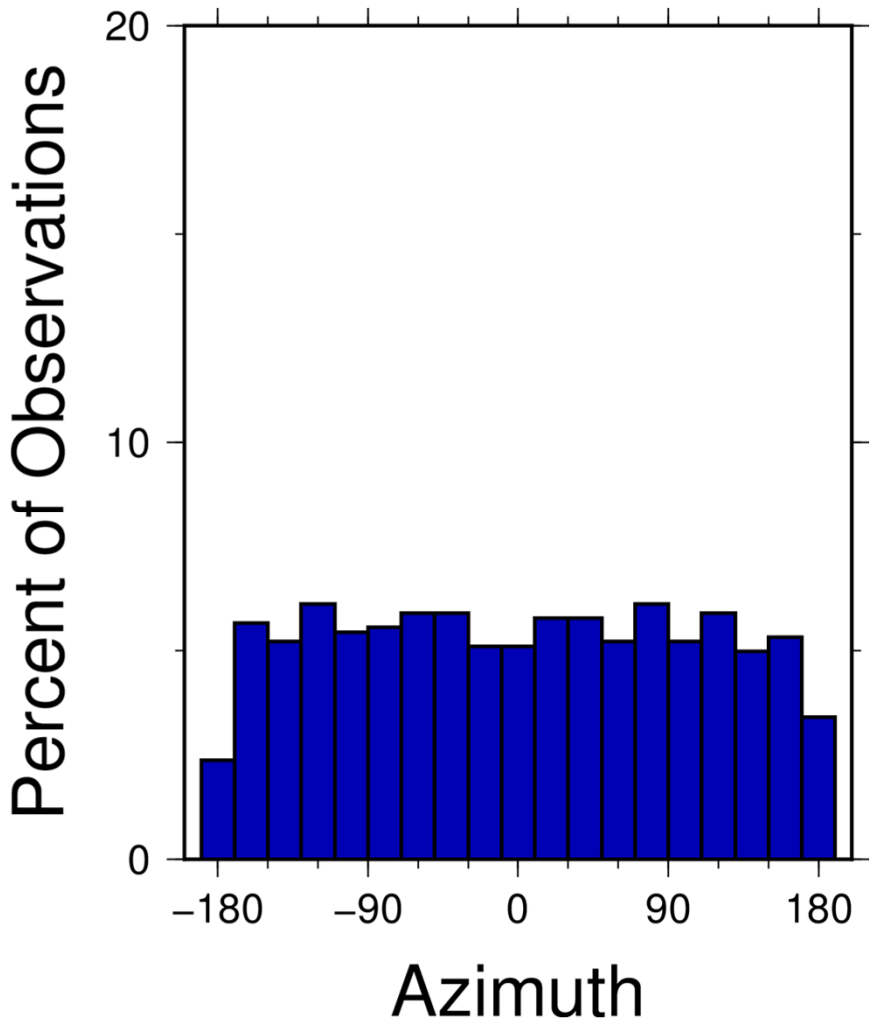


Sky plot for all GPS satellites for 1 day (30-Mar-2012)

Histogram for elevation and azimuth

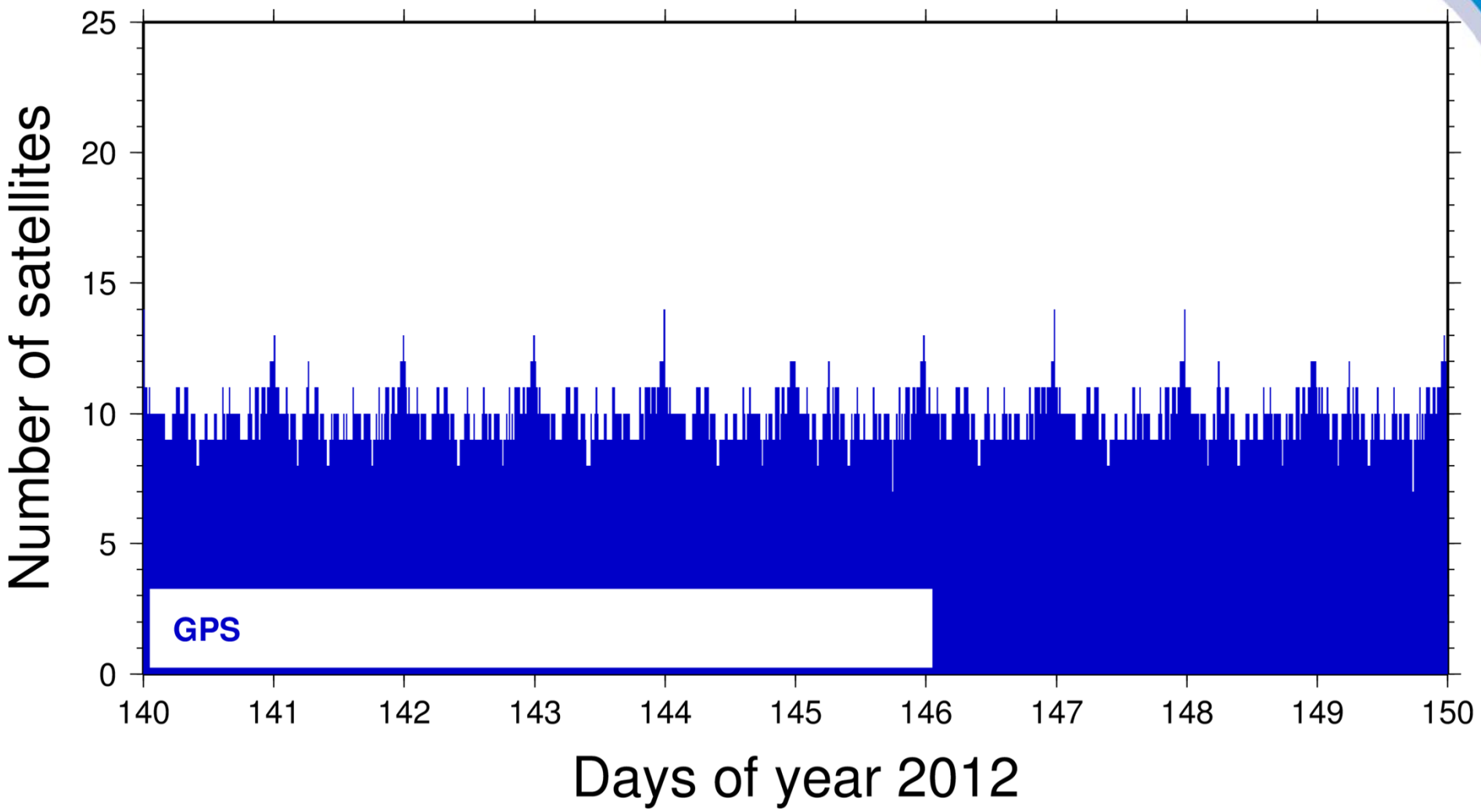
Amundson-Scott, South pole





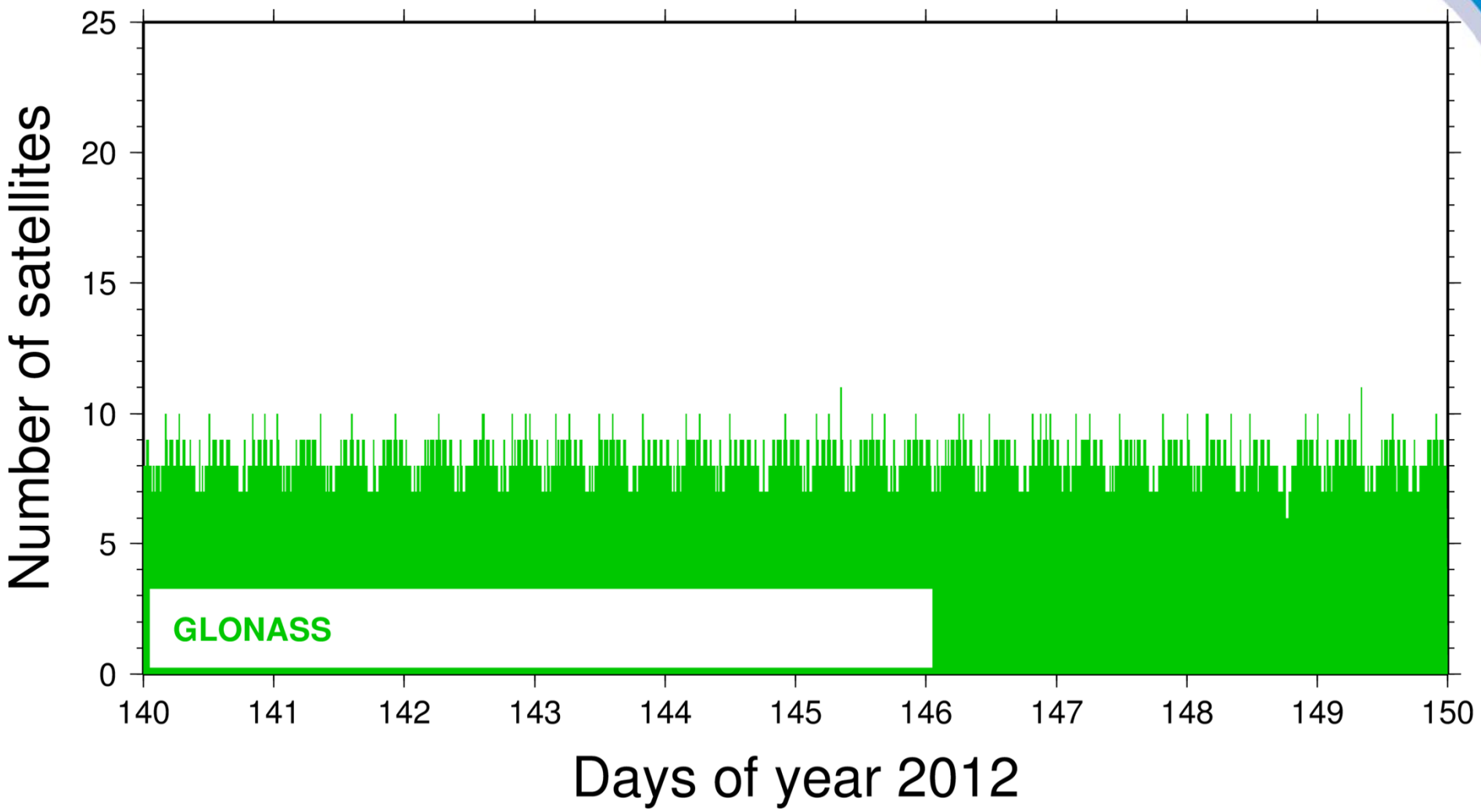
Sky plot for all GLONASS satellites for 1 day (30-Mar-2012)

Number of satellites in view for Zimmerwald



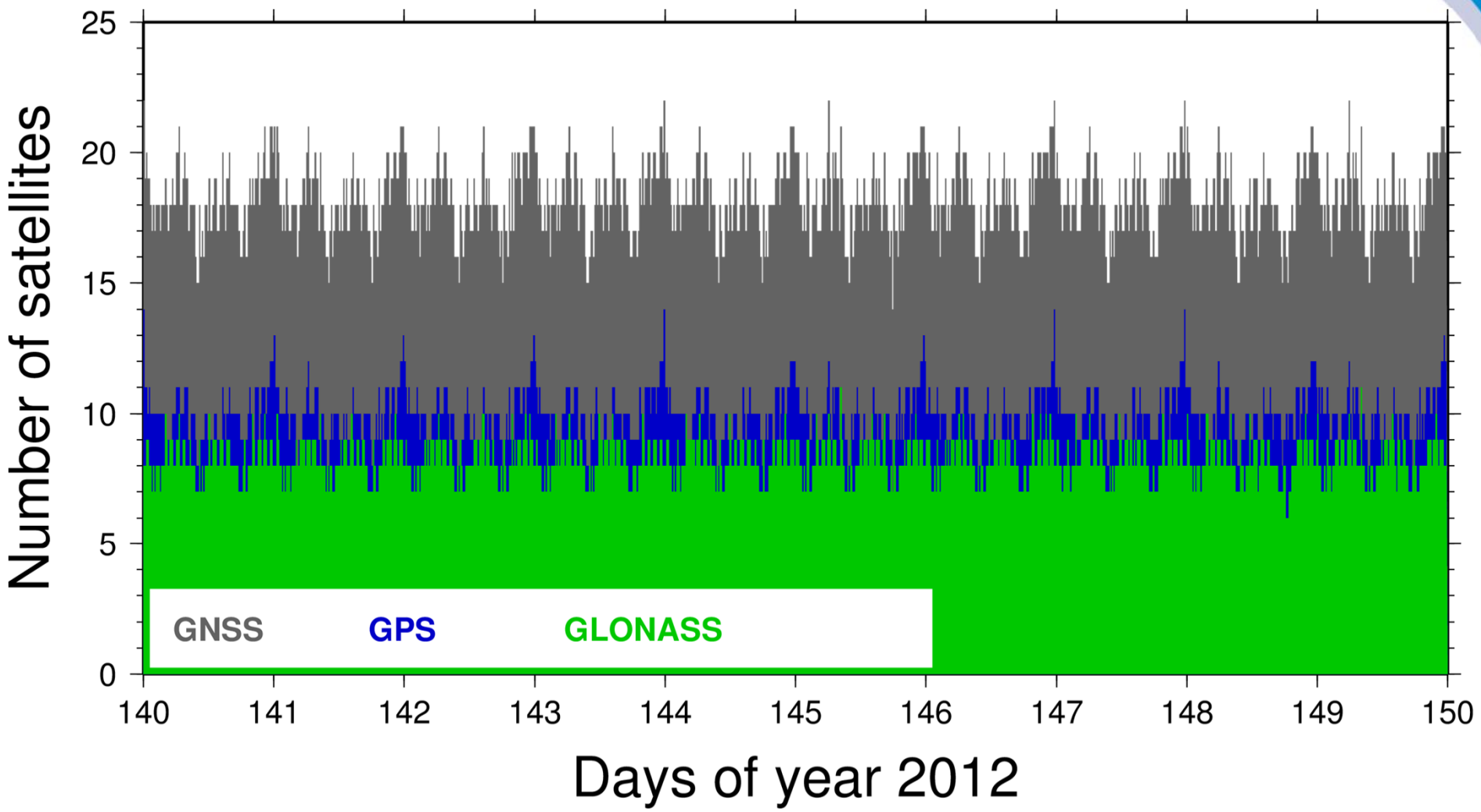
Based on 10 days in May 2012

Number of satellites in view for Zimmerwald



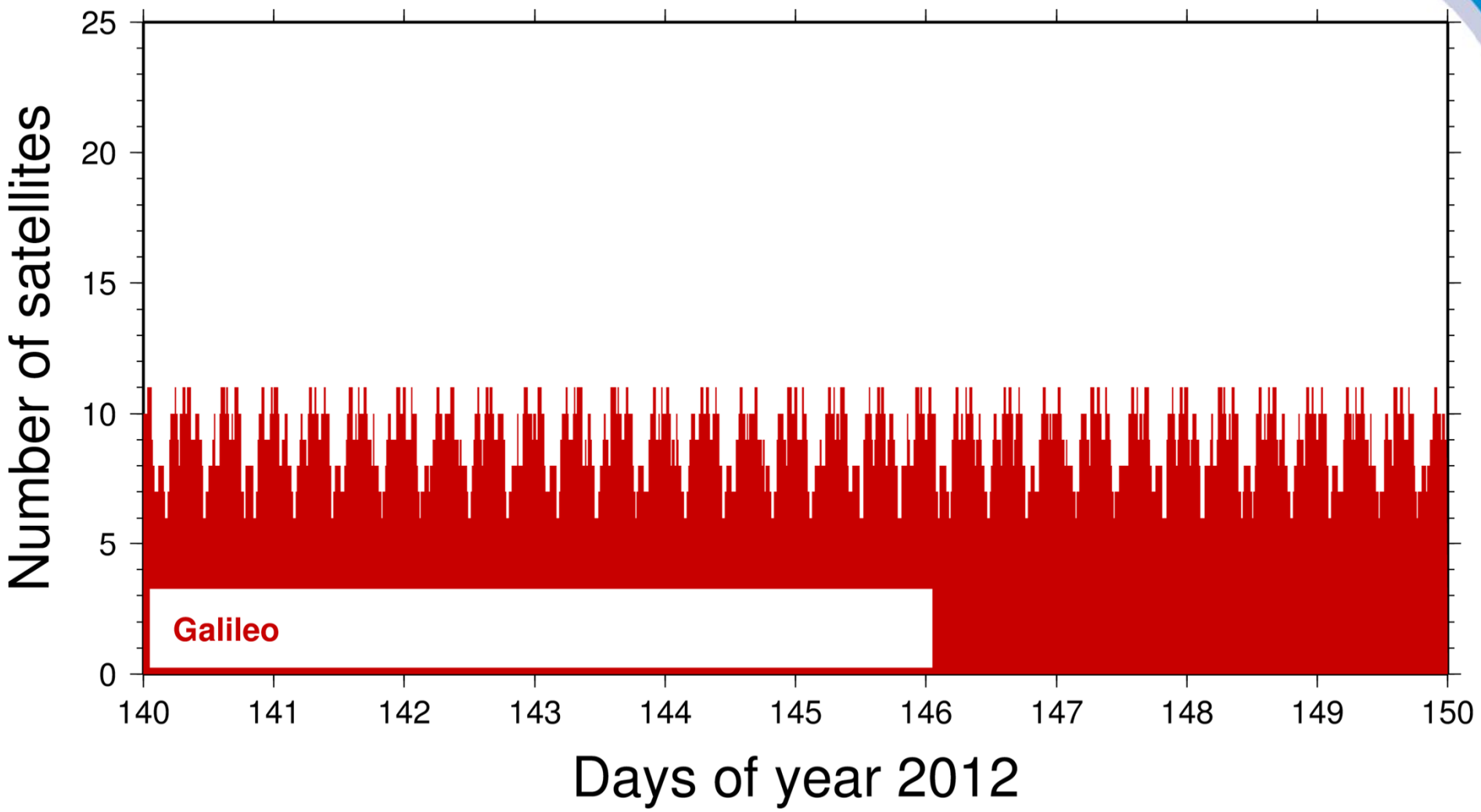
Based on 10 days in May 2012

Number of satellites in view for Zimmerwald



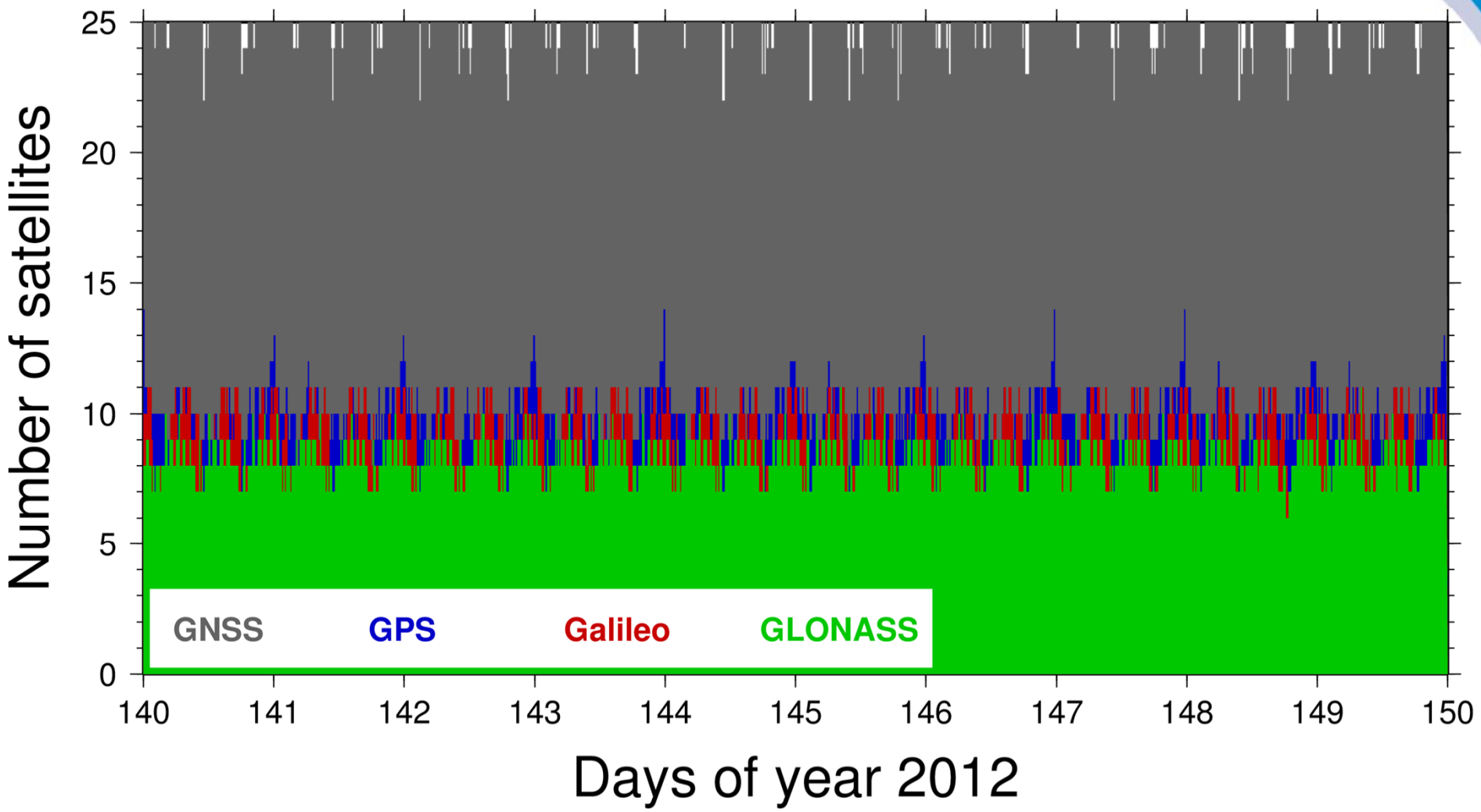
Based on 10 days in May 2012

Number of satellites in view for Zimmerwald



Based on 10 days in May 2012

Number of satellites in view for Zimmerwald



Based on 10 days in May 2012

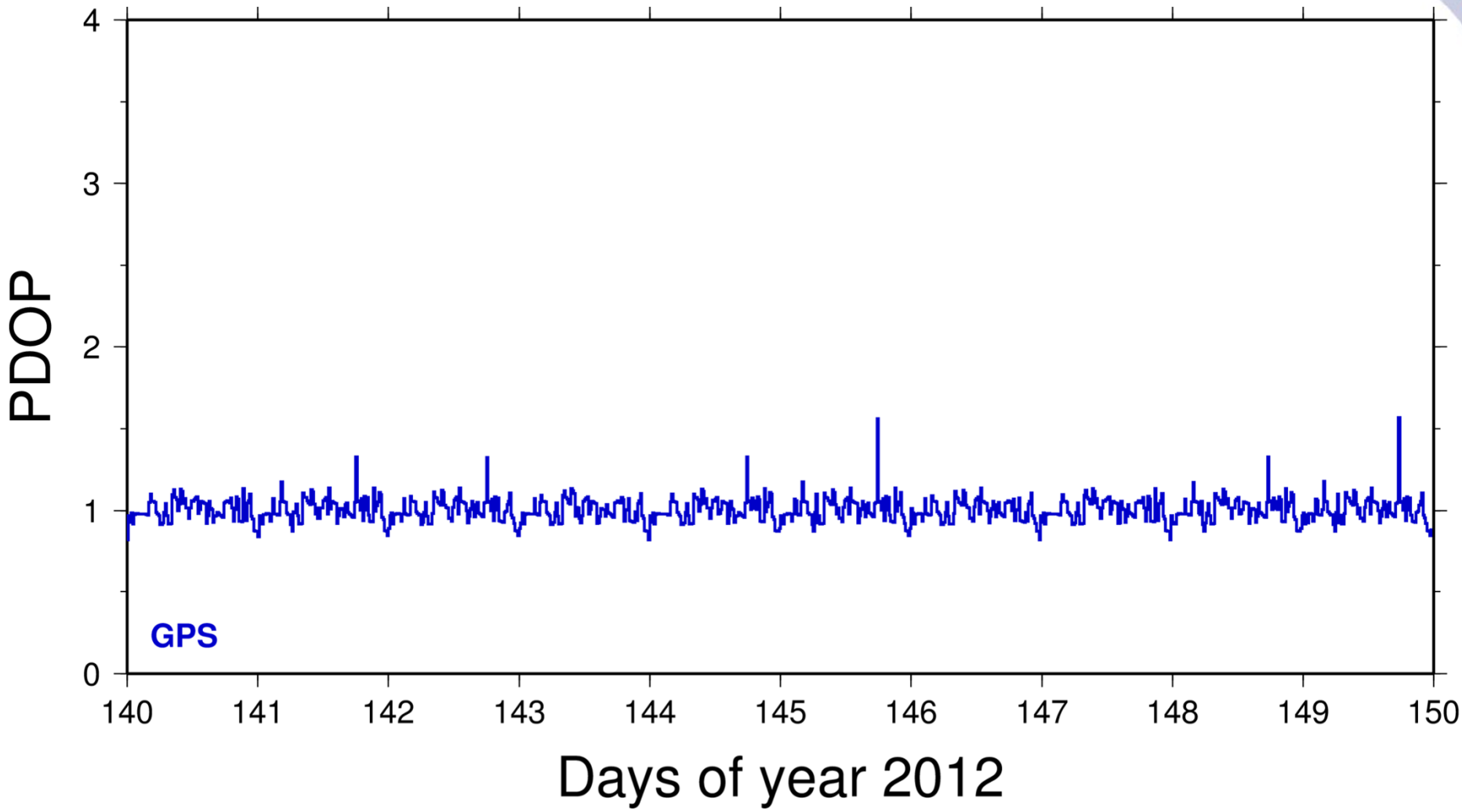
PDOP: Position Dilution of Precision

- PDOP values indicates, how good a station position can be determined with the current satellite geometry.
- It is computed from the reciprocal of the normalized volume of the body formed by all tracked satellites and the receiver position.
- The PDOP can be extracted from the trace of the cofactor matrix:

$$\boldsymbol{C_{YY}} = \begin{bmatrix} q_{XX} & q_{XY} & q_{XZ} \\ q_{YX} & q_{YY} & q_{YZ} \\ q_{ZX} & q_{ZY} & q_{ZZ} \end{bmatrix} \qquad \mathrm{PDOP} = \sqrt{q_{XX} + q_{YY} + q_{ZZ}}$$

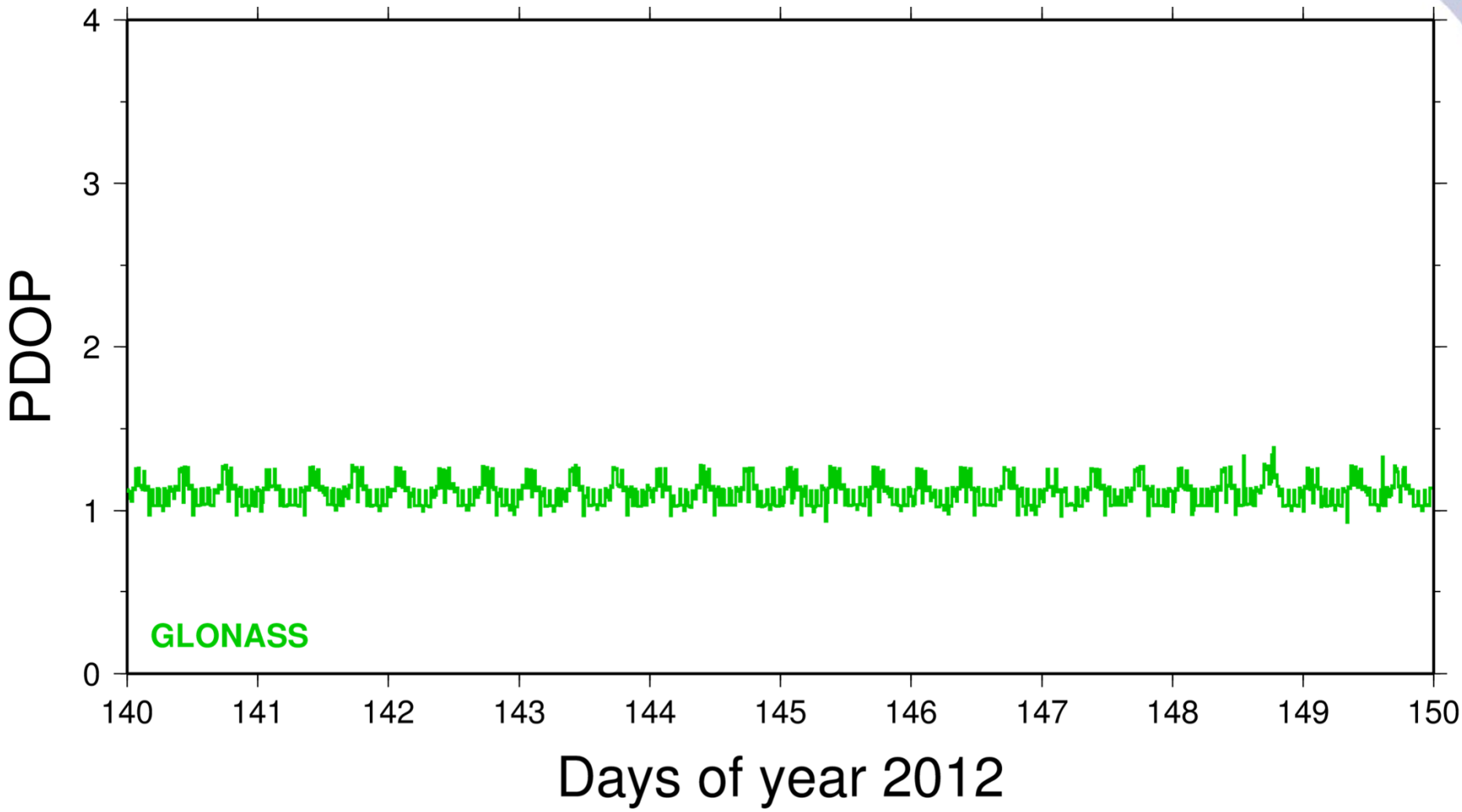
- The smaller the PDOP value is the better a position can be derived.

PDOP for Zimmerwald



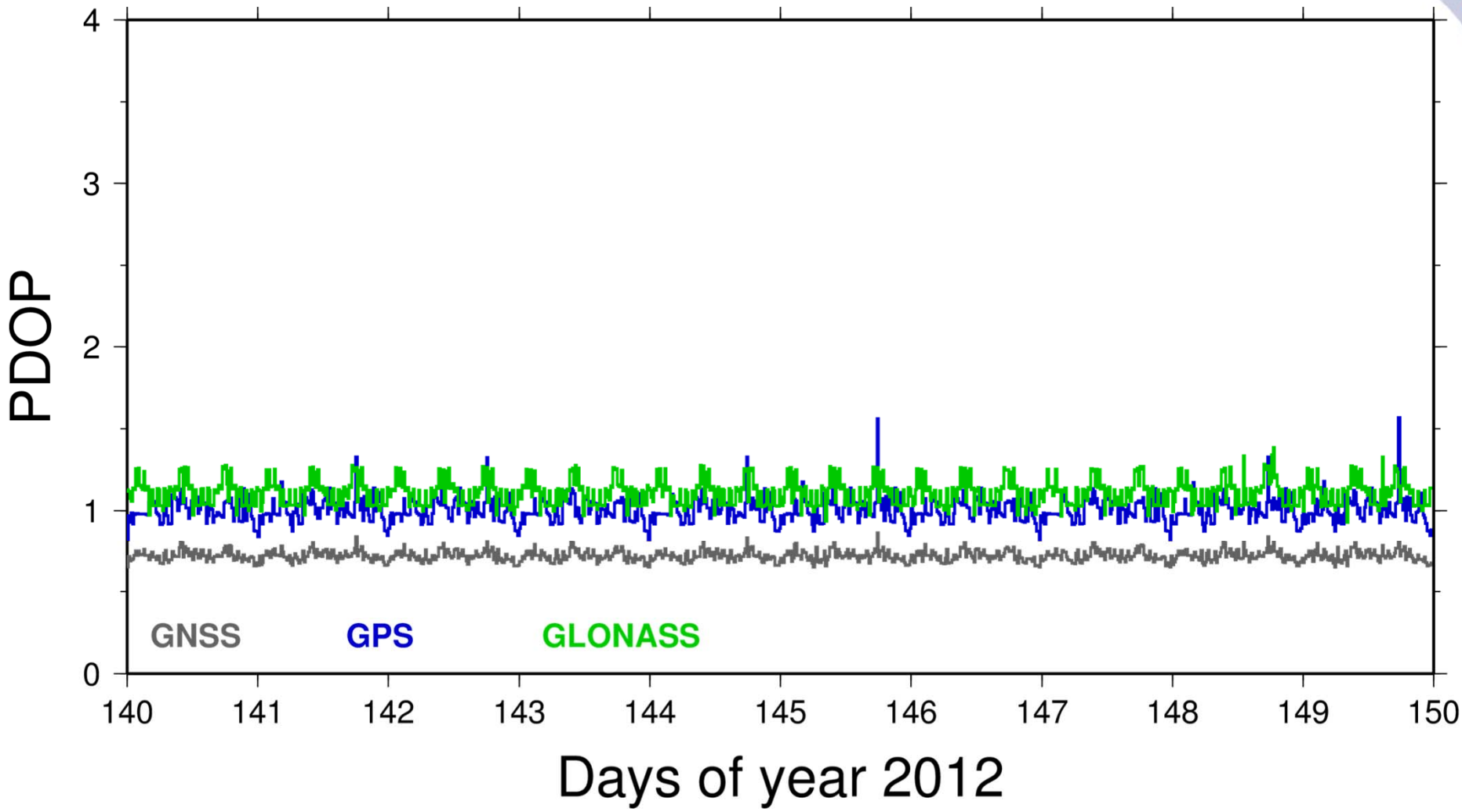
Computed based on 10 days in May 2012

PDOP for Zimmerwald



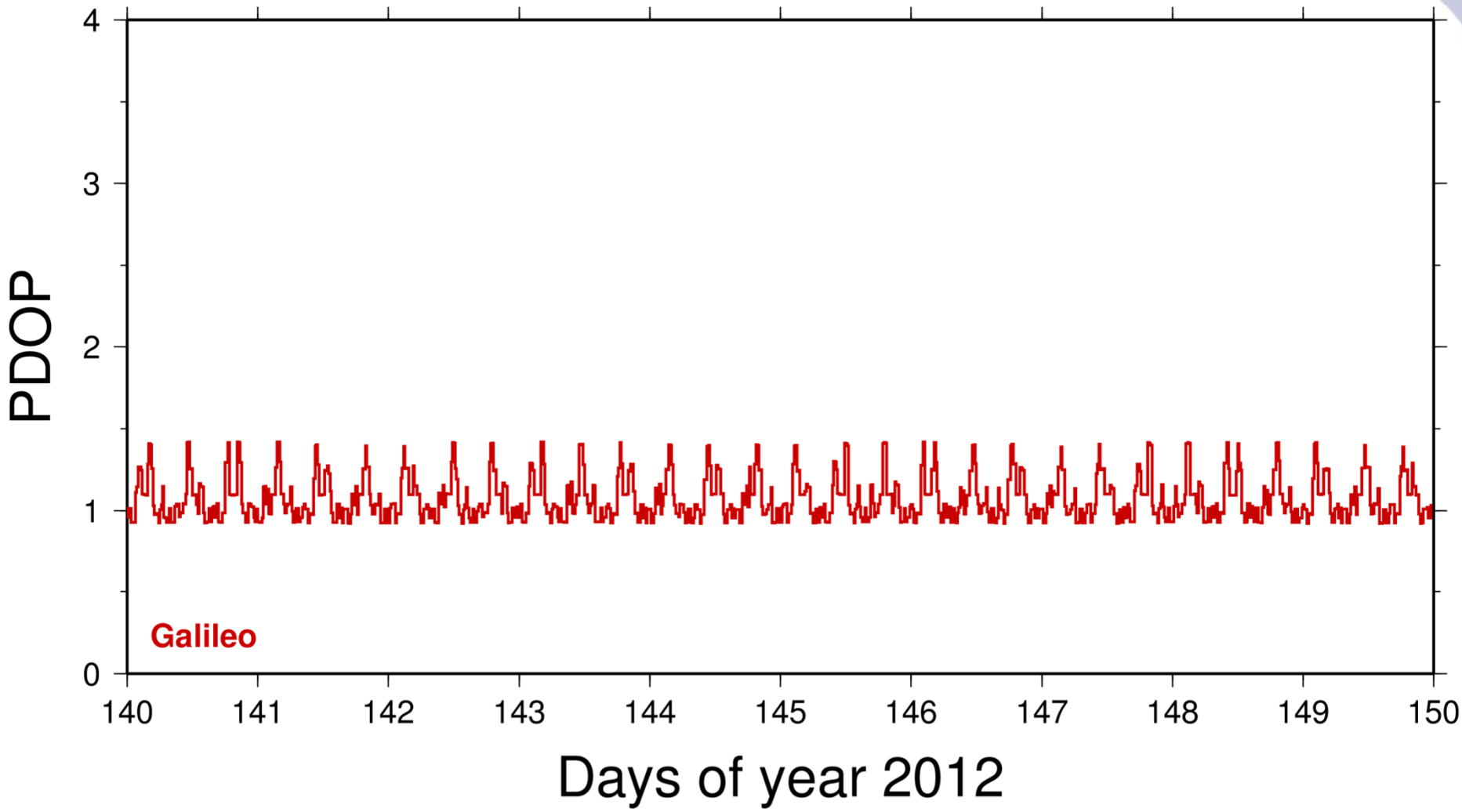
Computed based on 10 days in May 2012

PDOP for Zimmerwald



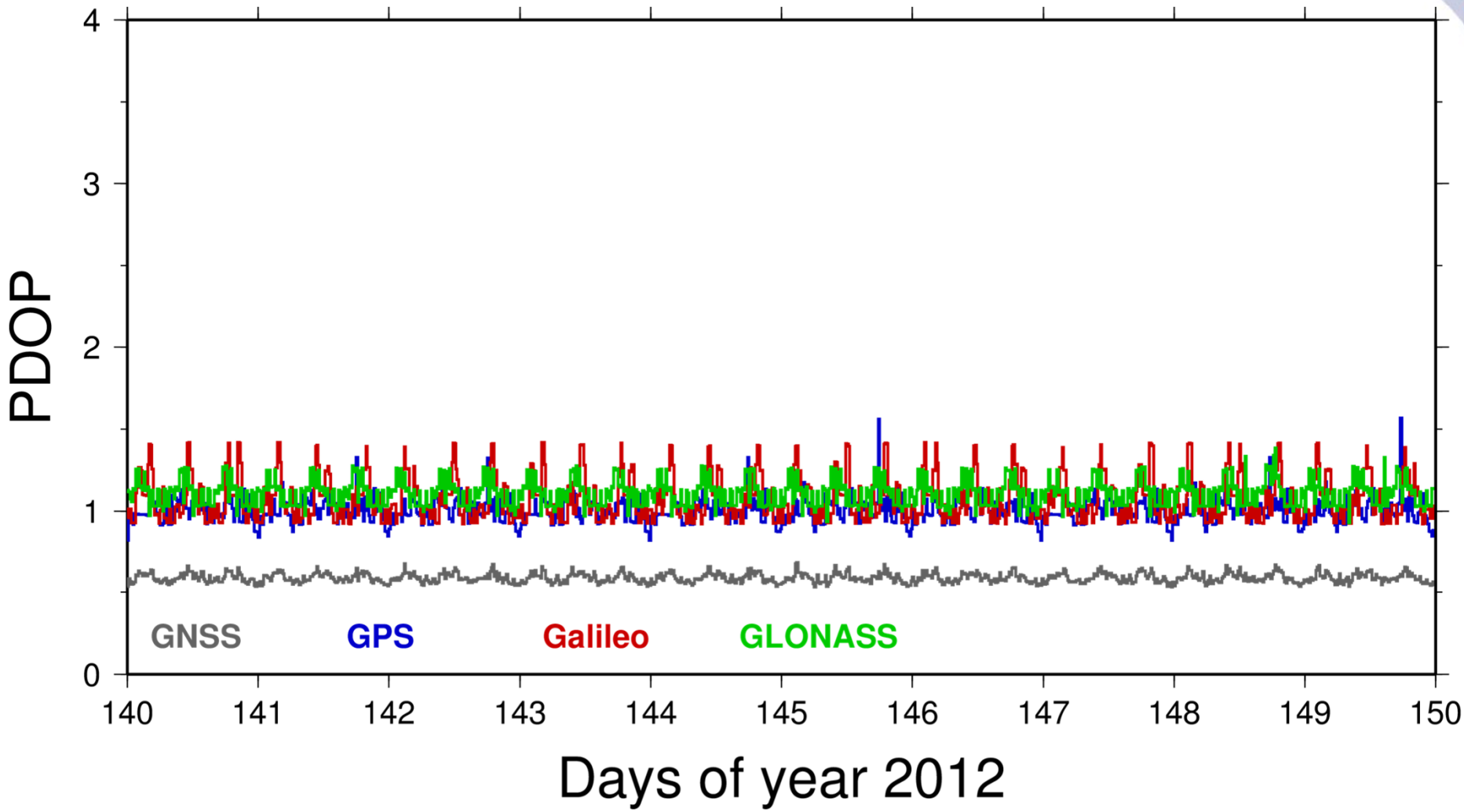
Computed based on 10 days in May 2012

PDOP for Zimmerwald



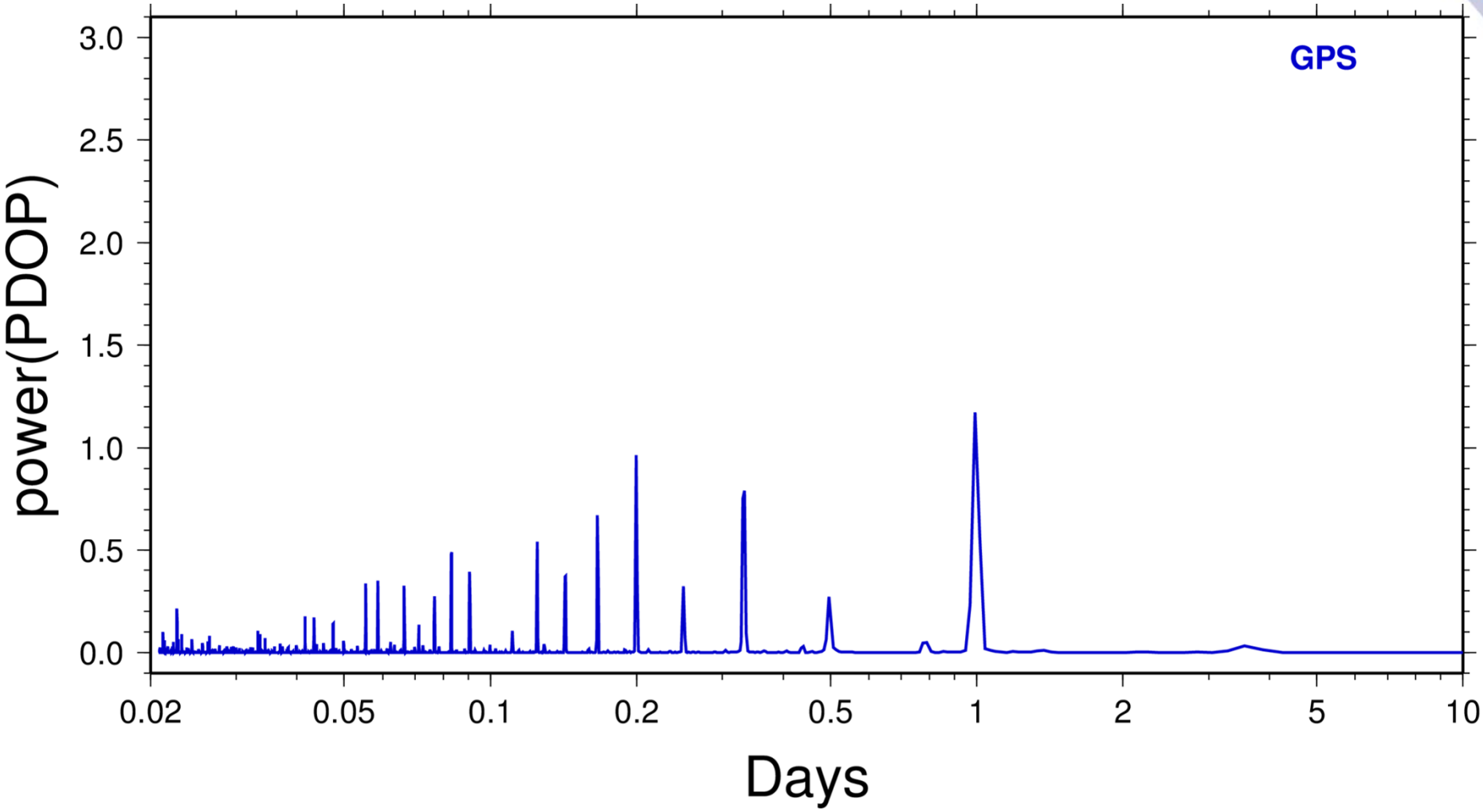
Computed based on 10 days (fictive constellation)

PDOP for Zimmerwald



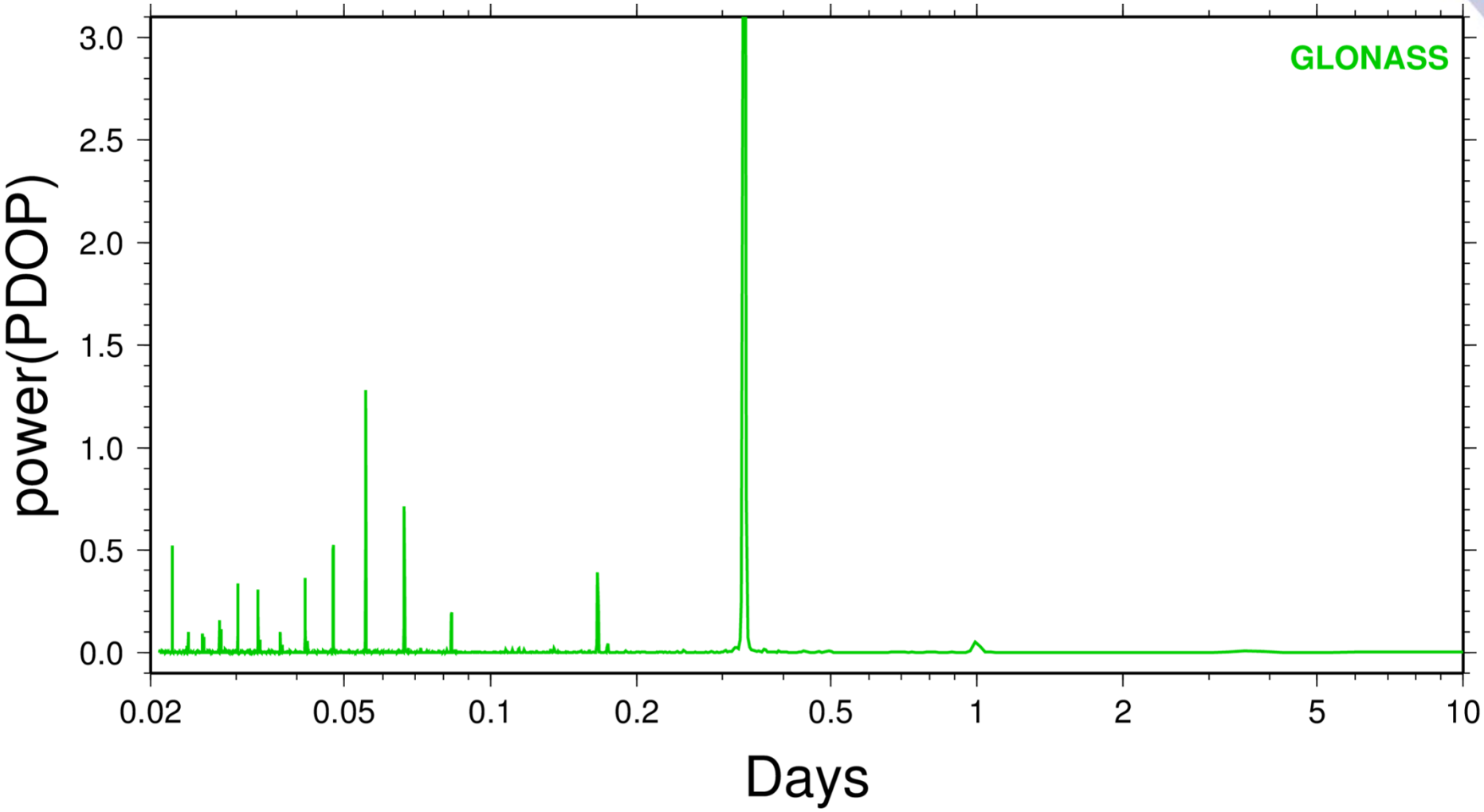
Computed based on 10 days in May 2012

Spectral analysis of the PDOP for Zimmerwald



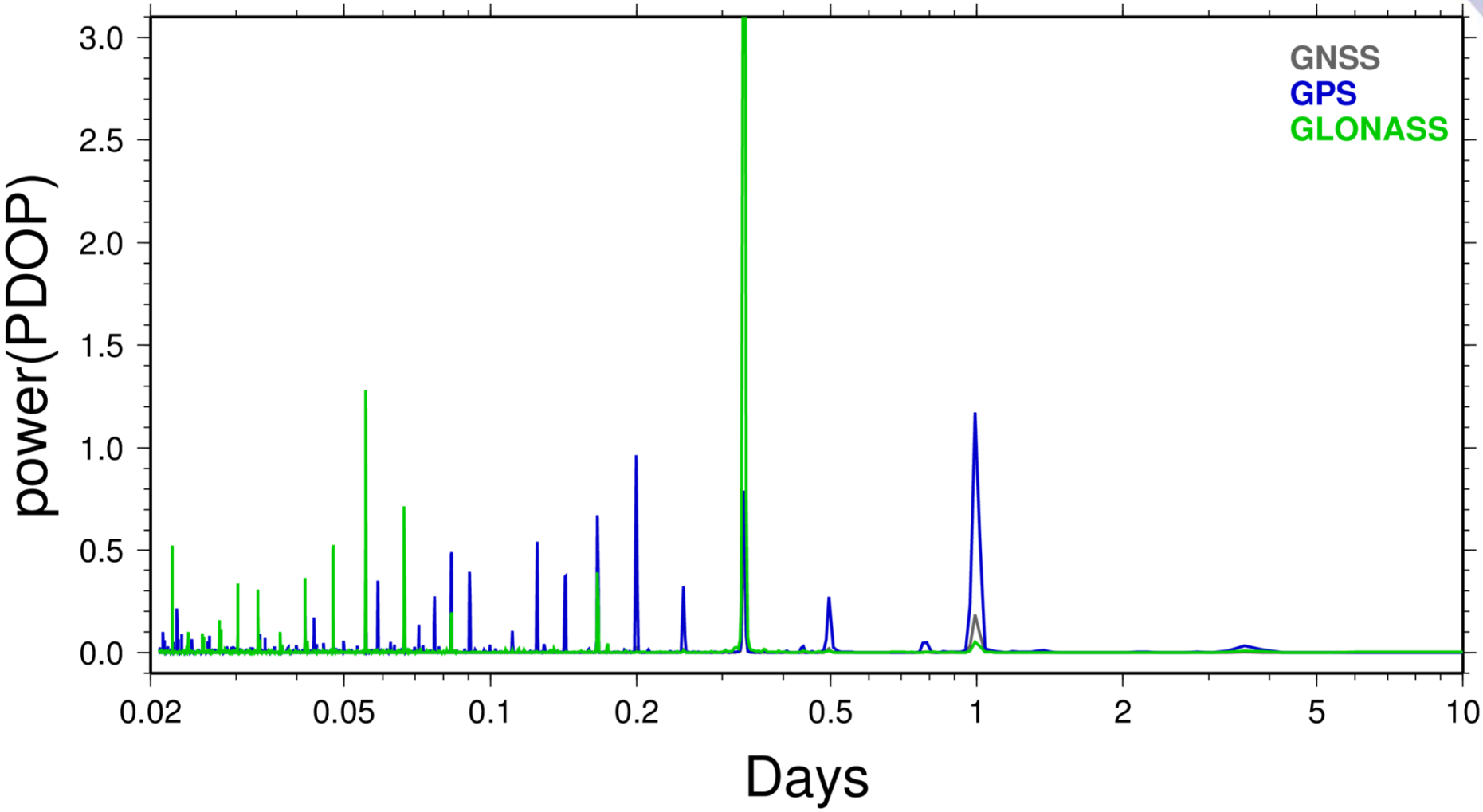
Computed based on 60 days in April/May 2012

Spectral analysis of the PDOP for Zimmerwald



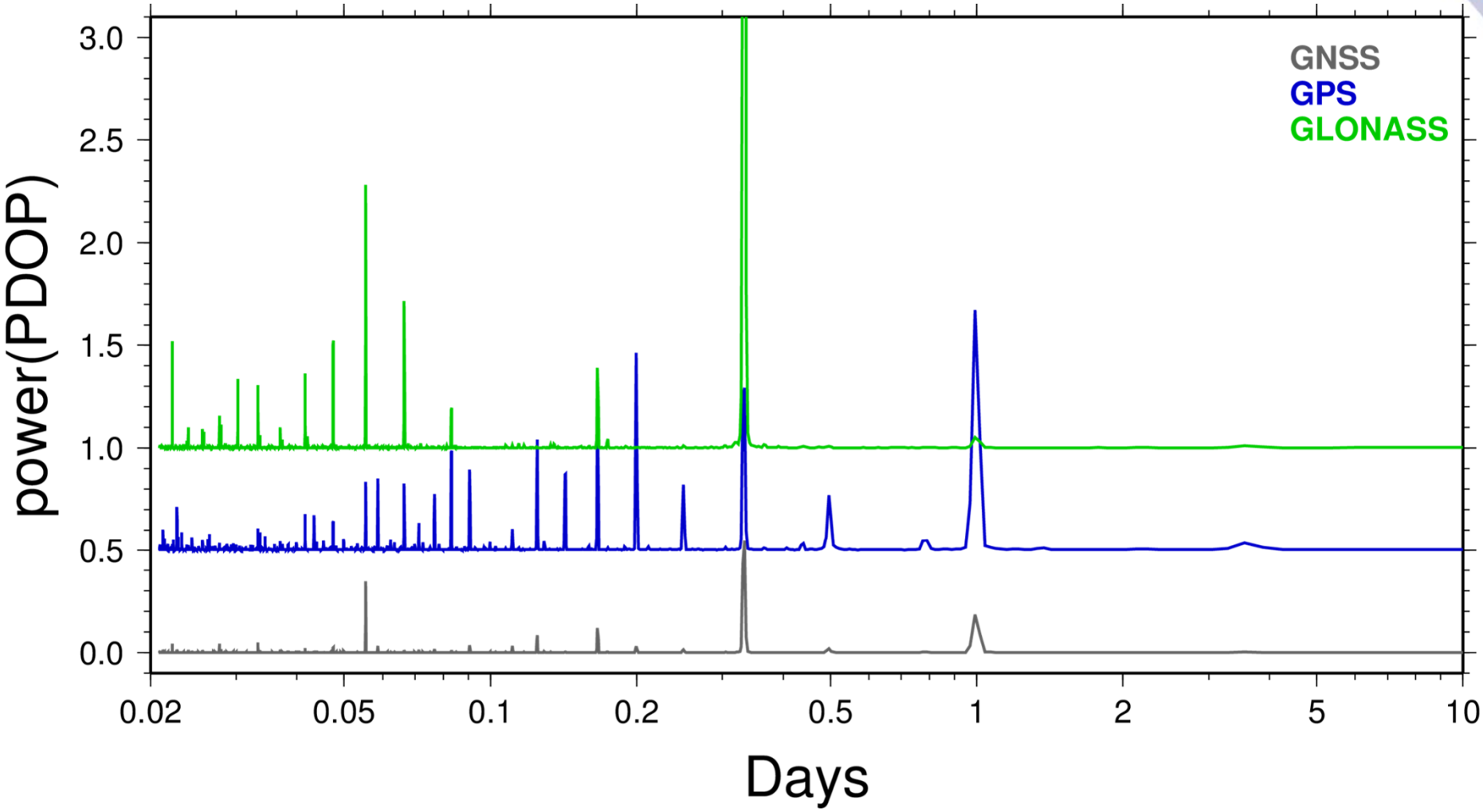
Computed based on 60 days in April/May 2012

Spectral analysis of the PDOP for Zimmerwald



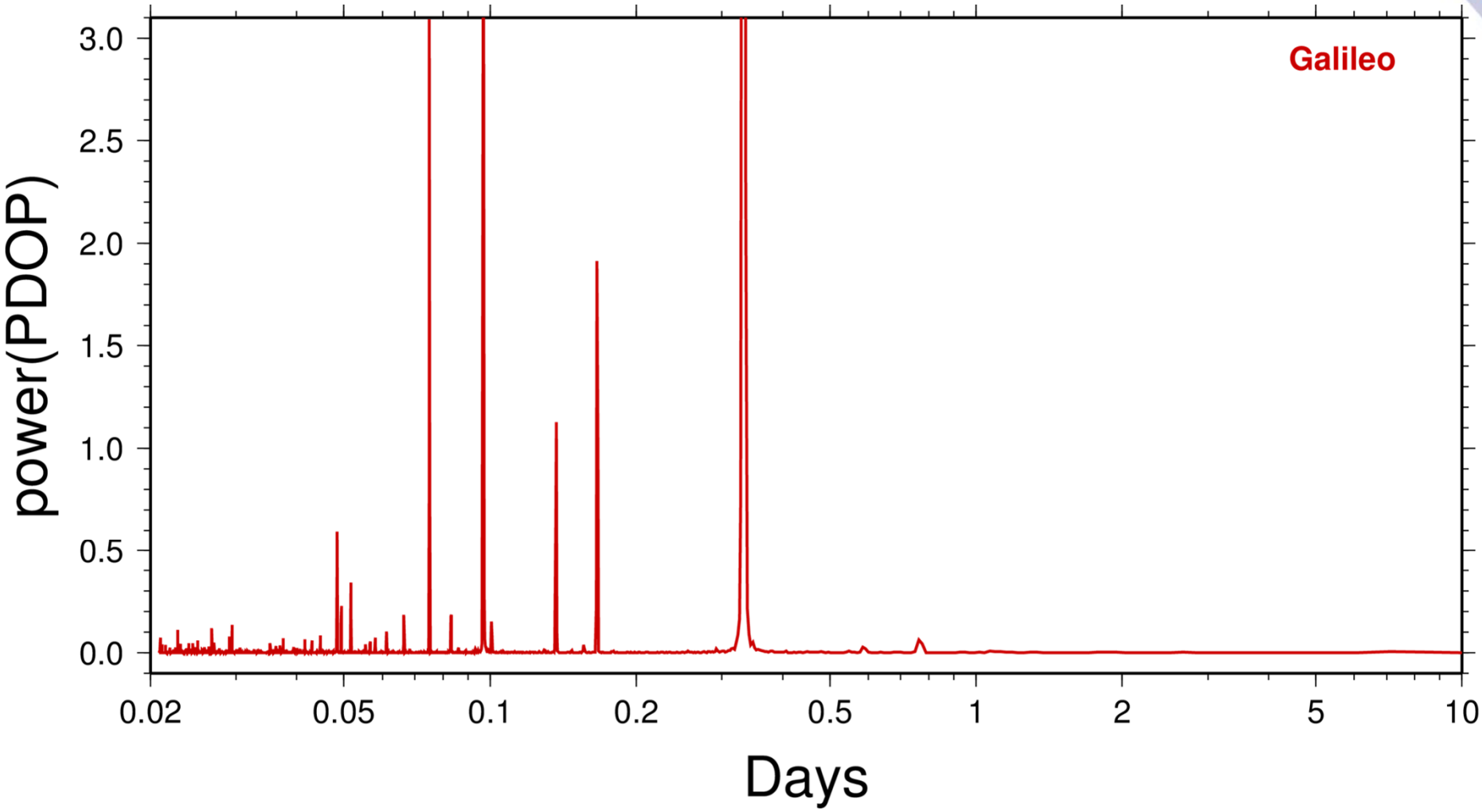
Computed based on 60 days in April/May 2012

Spectral analysis of the PDOP for Zimmerwald



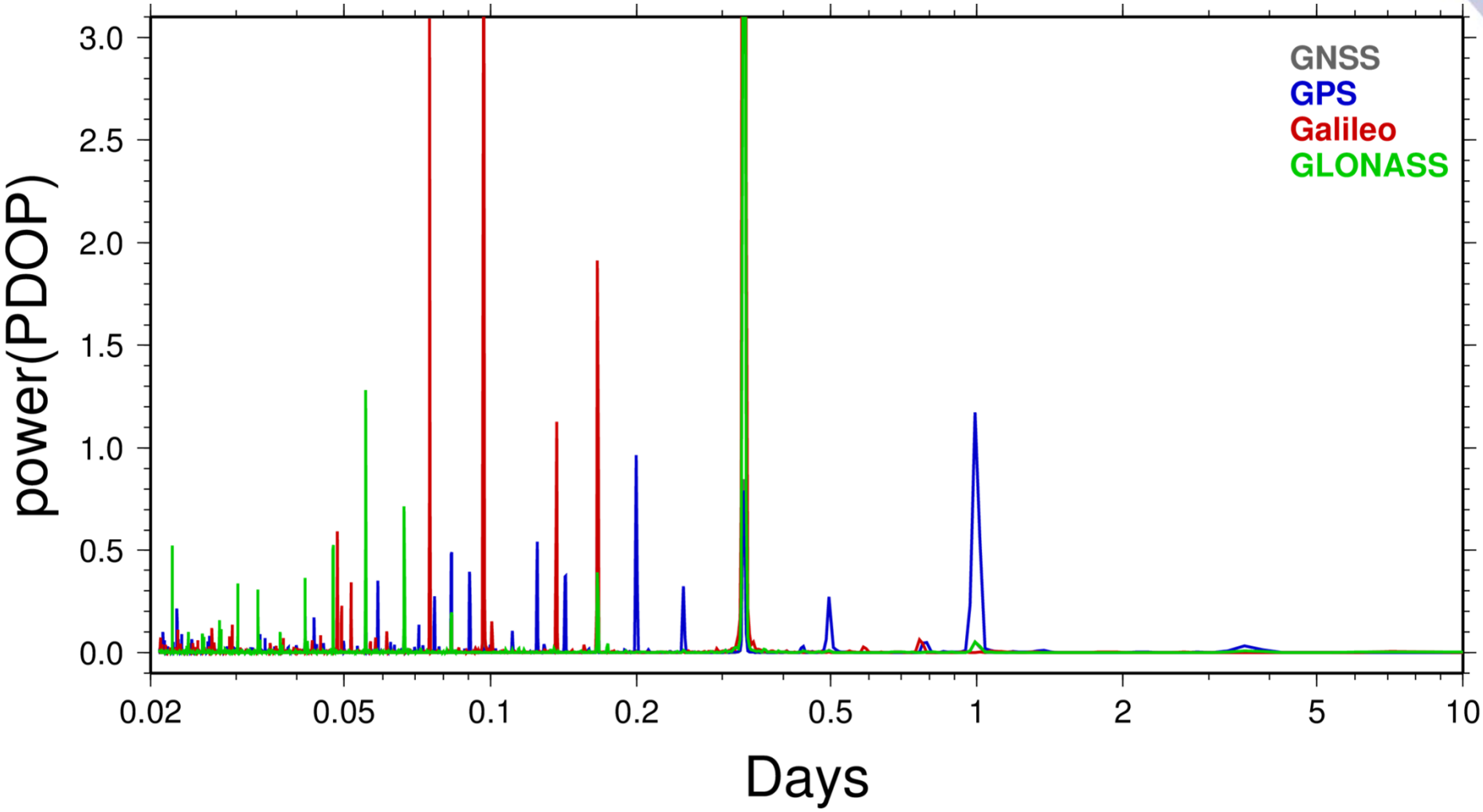
Computed based on 60 days in April/May 2012

Spectral analysis of the PDOP for Zimmerwald



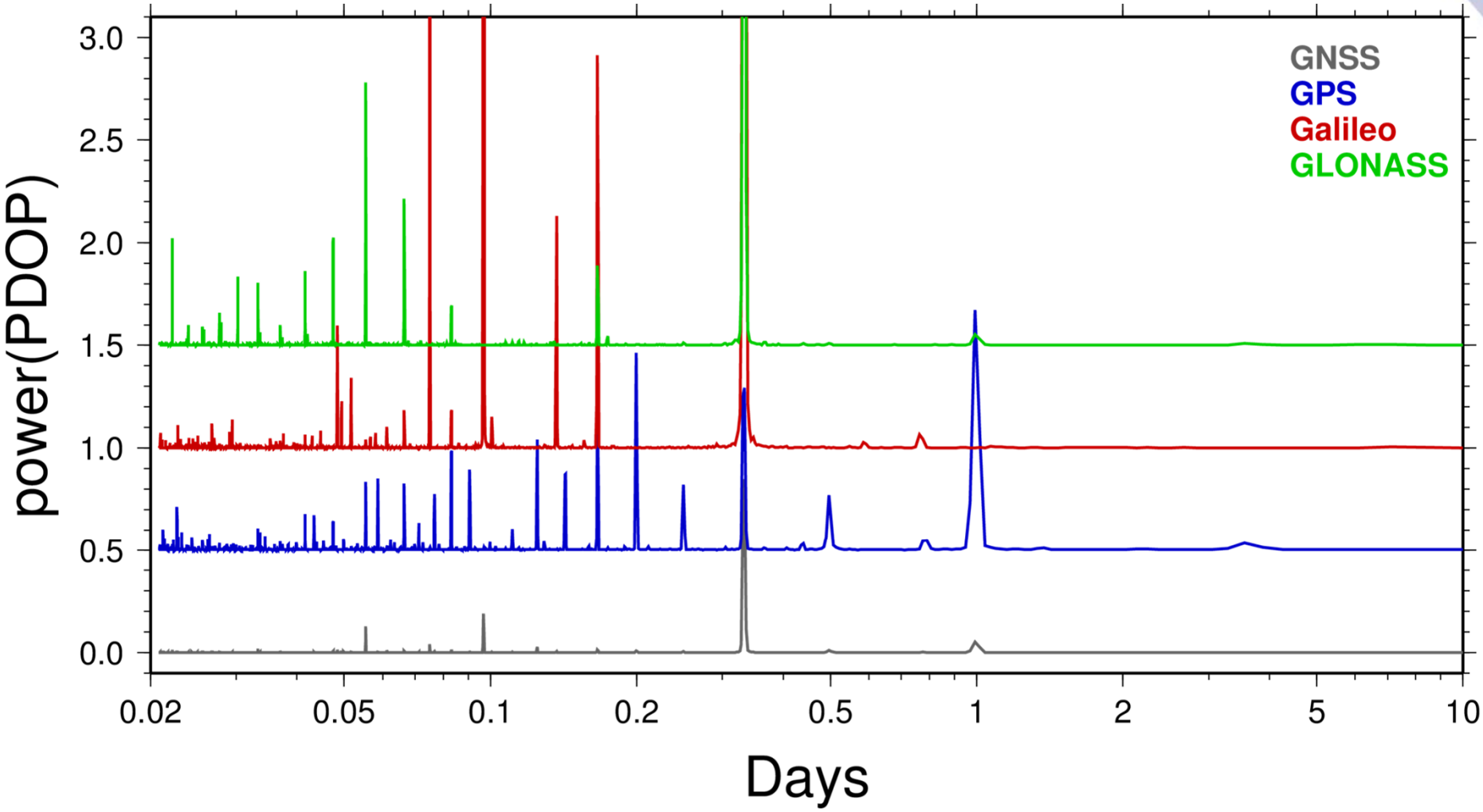
Computed based on 60 days (fictive constellation)

Spectral analysis of the PDOP for Zimmerwald



Computed based on 60 days in April/May 2012

Spectral analysis of the PDOP for Zimmerwald



Computed based on 60 days in April/May 2012