Multiconstellation GNSS with the advent of Galileo

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Astronomisches Institut, Universität Bern

1st GAL WORKSHOP
24. May 2013, Como, Italy

Outline

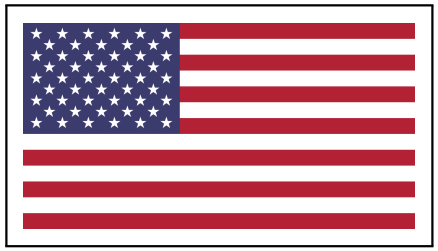
IGS MGEX: What and Why?

CODE–Contribution to IGS MGEX

Why going from GPS–only to multi–GNSS?

Summary

GNSS: Situation today



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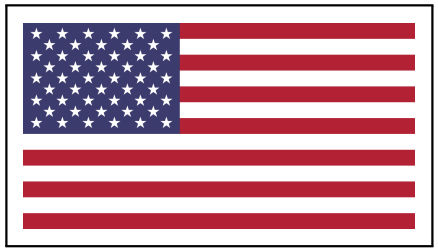

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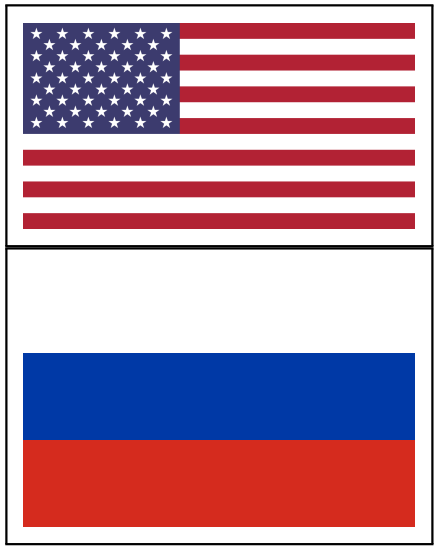

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Russia: ГЛОНАСС
Глобальная навигационная спутниковая система

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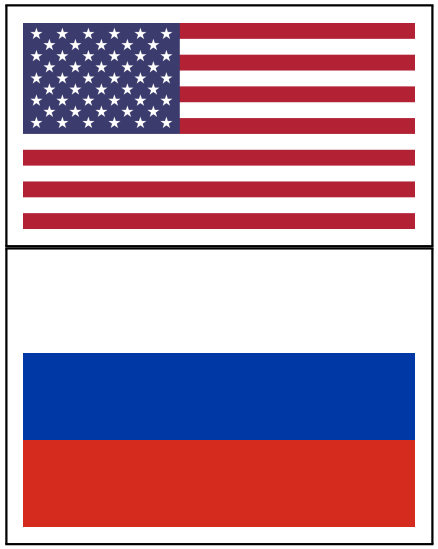

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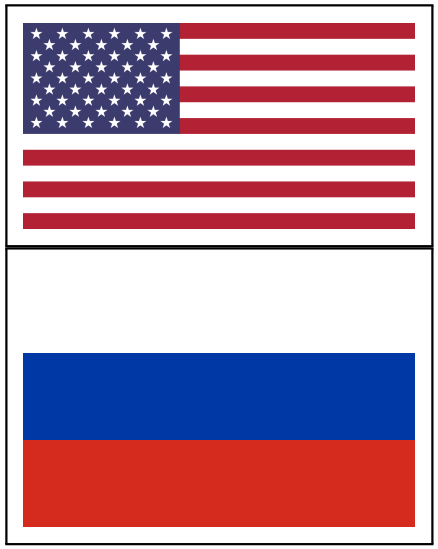

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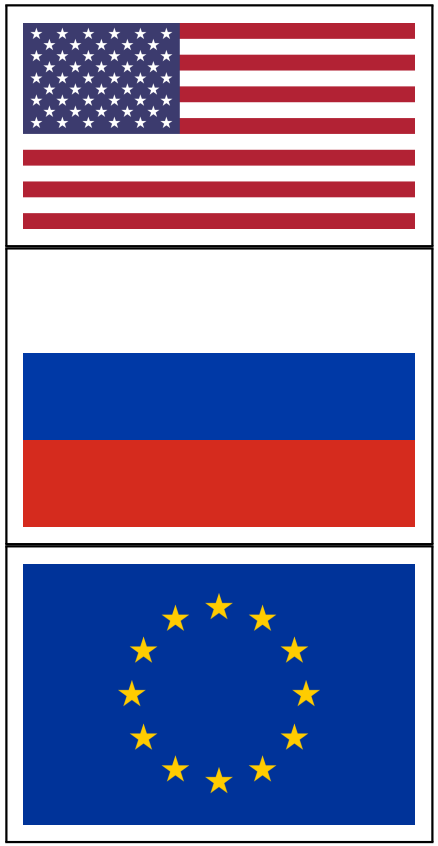

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Europe: Galileo
Nominal constellation of 27 satellites

GPS: Global Positioning System

- Currently 32 active satellites in 6 orbital planes
- Semi-major axis $a = 26\,500\,\mathrm{km}$, inclination $i = 55°$
- Revolution period $11^{\mathrm{h}}\ 58^{\mathrm{m}}$
  (same constellation after 2 revolutions within 1 sidereal day)
- Repeatition rates:
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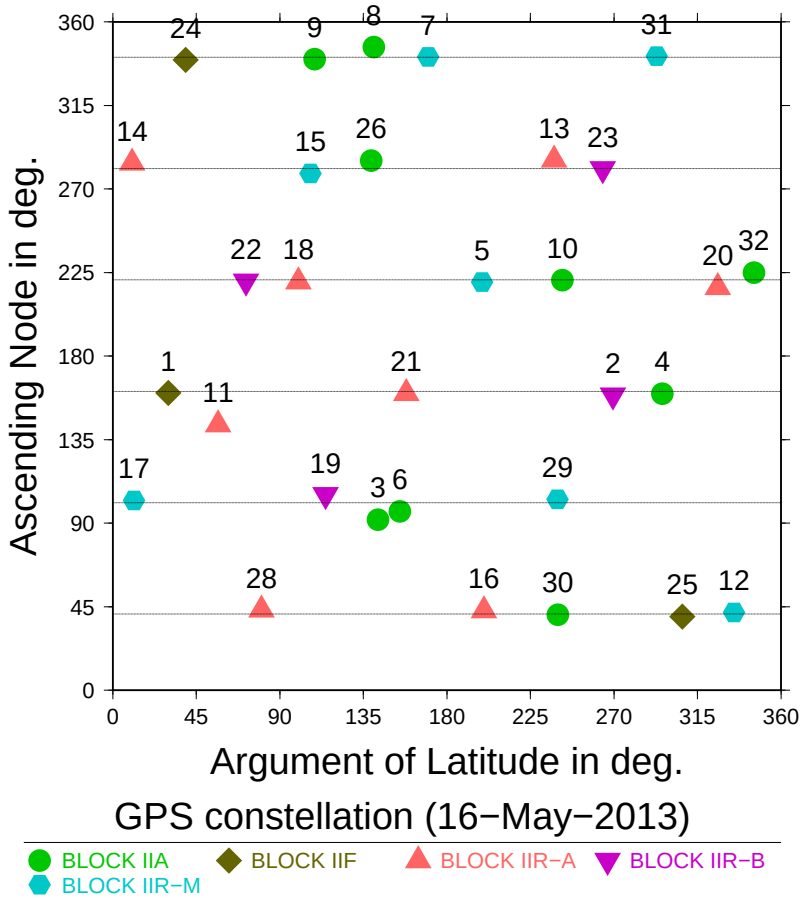

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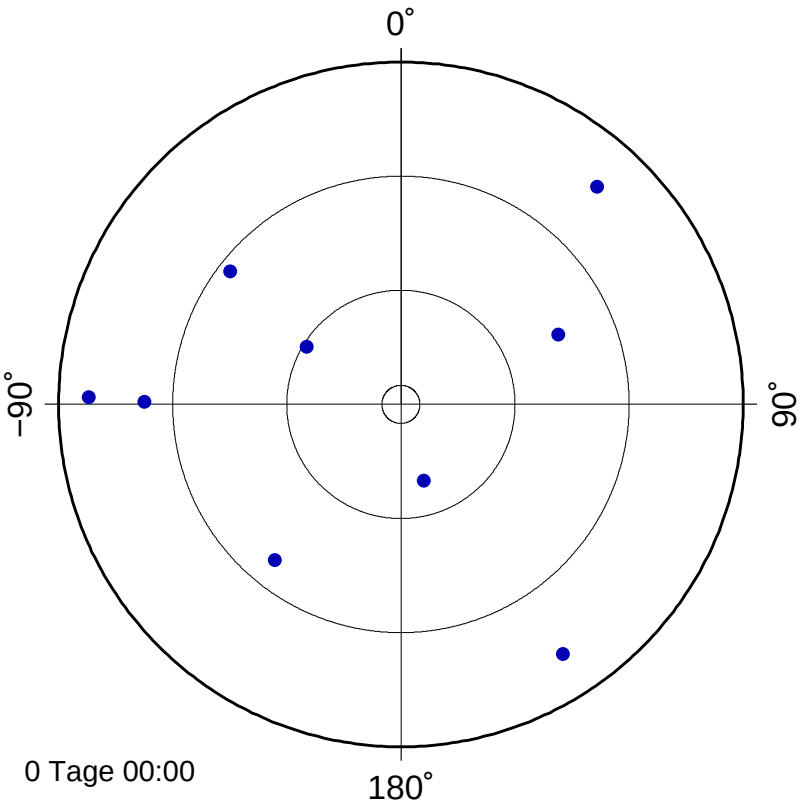

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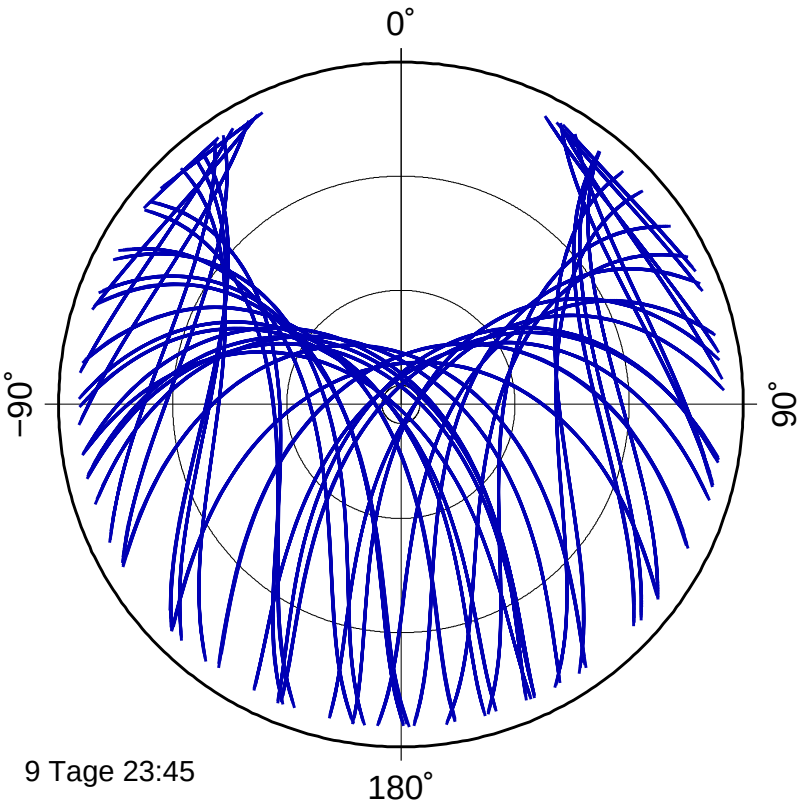

GLONASS: Global Navigation Satellite System

- nominally 24 active satellites in 3 planes (24 Sat. today)
- Semi-major axis $a = 25\,500\,\mathrm{km}$, inclination $i = 65°$
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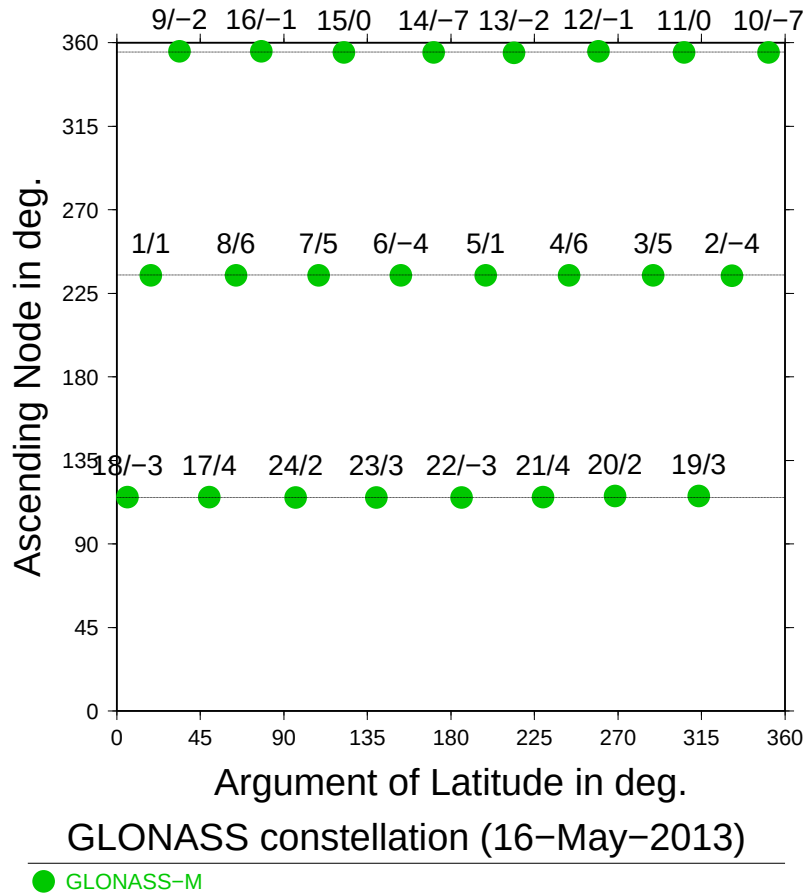

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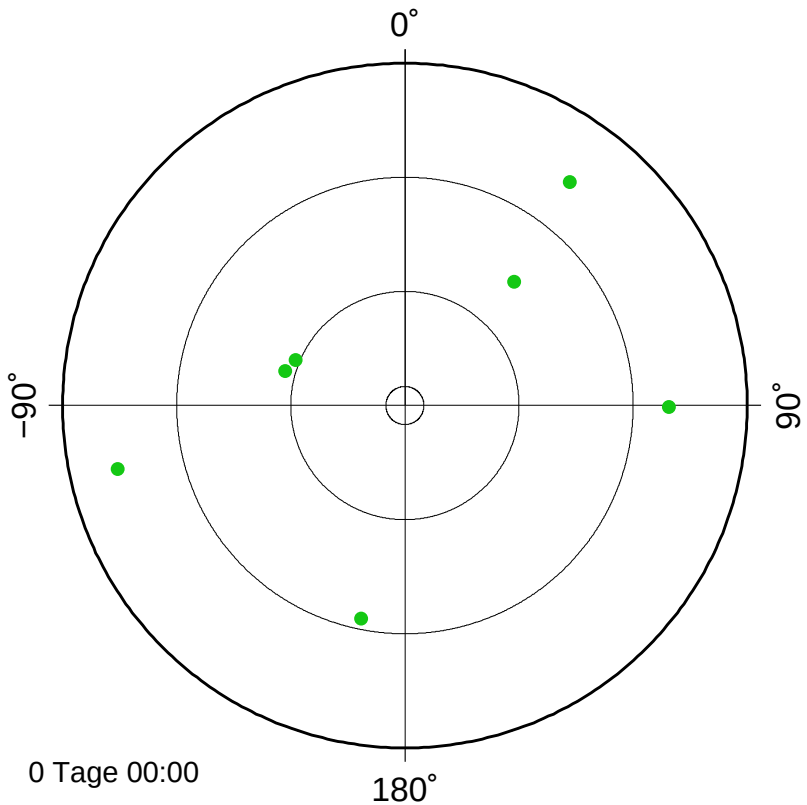

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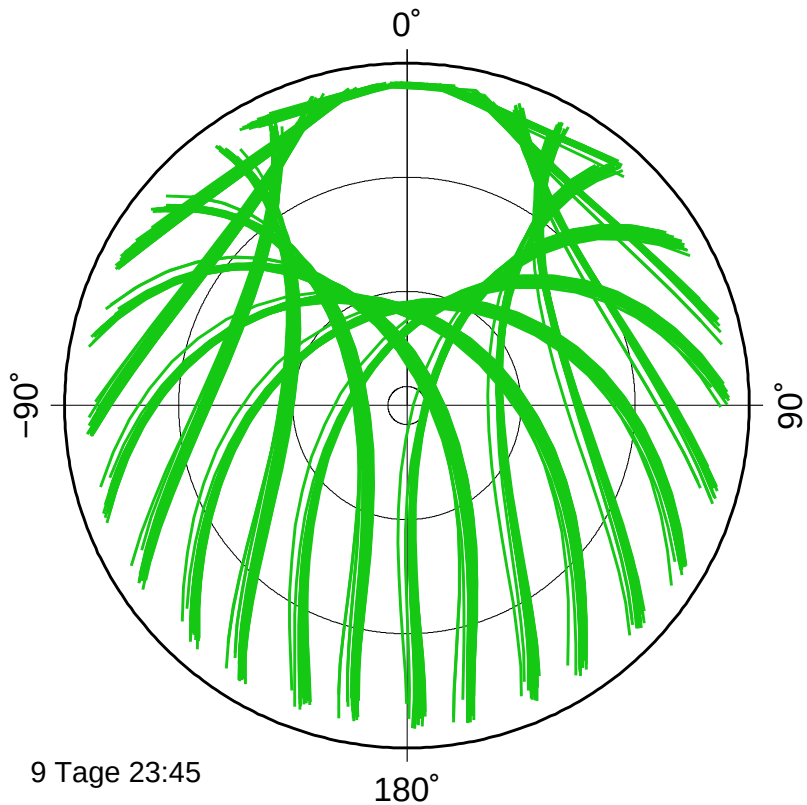

Galileo: the European GNSS

- nominally 27 active satellites in 3 orbital planes
- Semi-major axis $a = 30\,000\,\mathrm{km}$, inclination $i = 56°$
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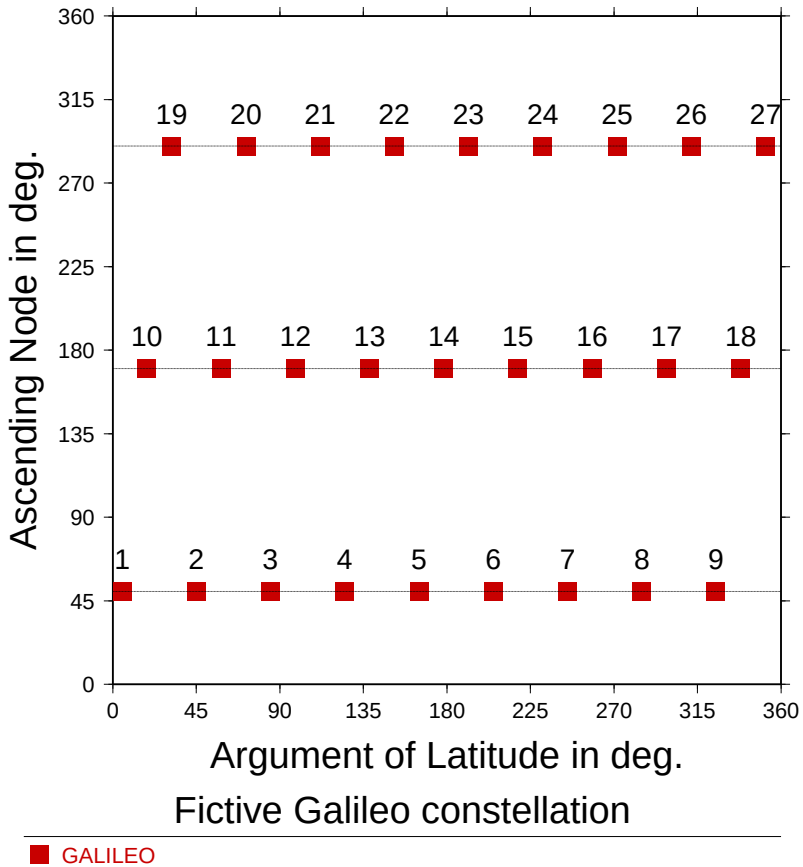

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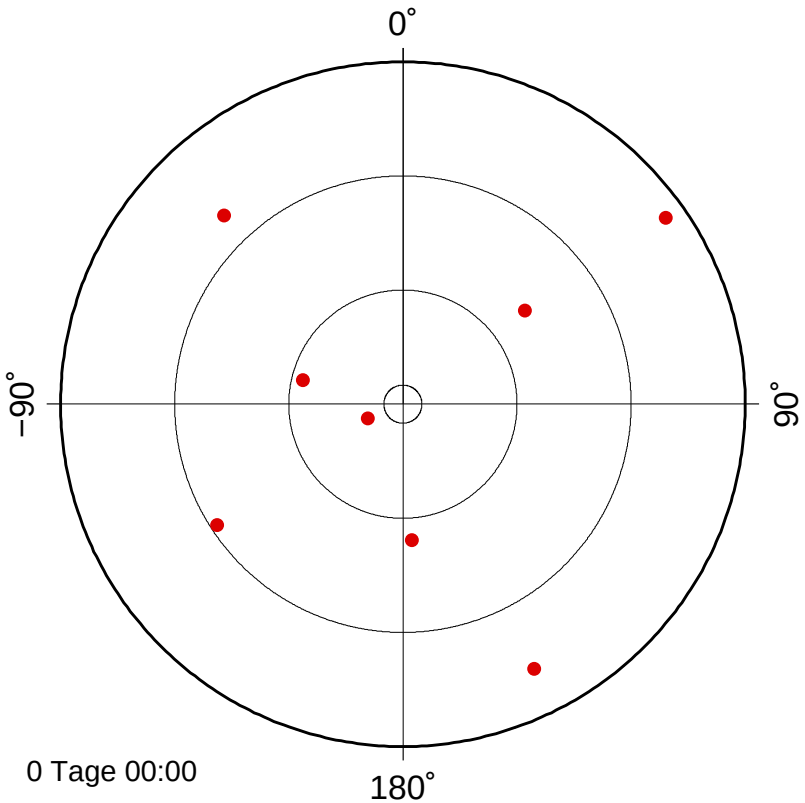

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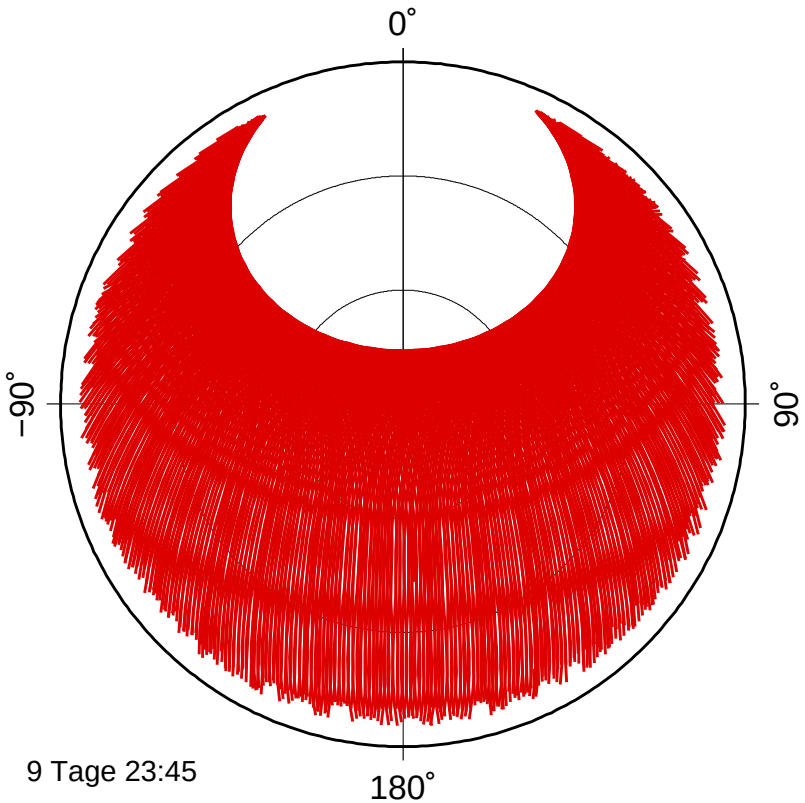
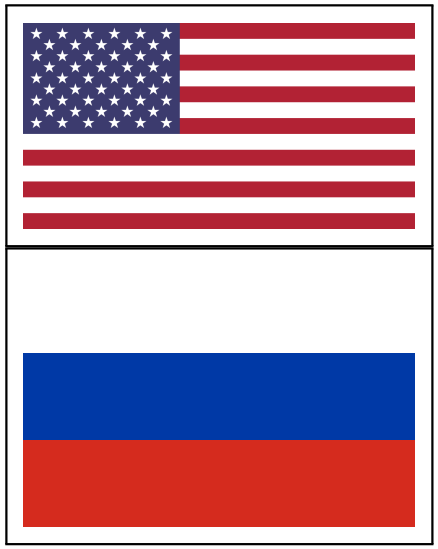


Orbit characteristics of the GNSS



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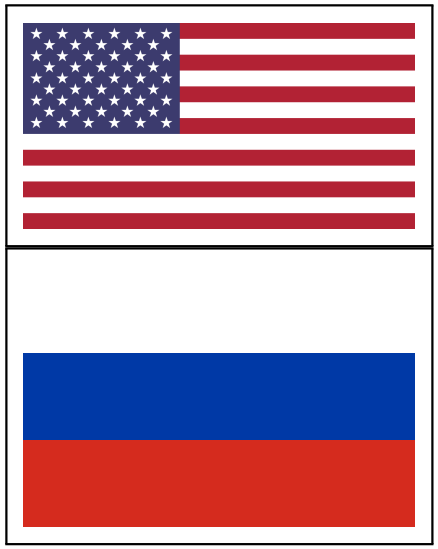

USA: GPS

32 active satellites (nominal: 24); 2 frequencies

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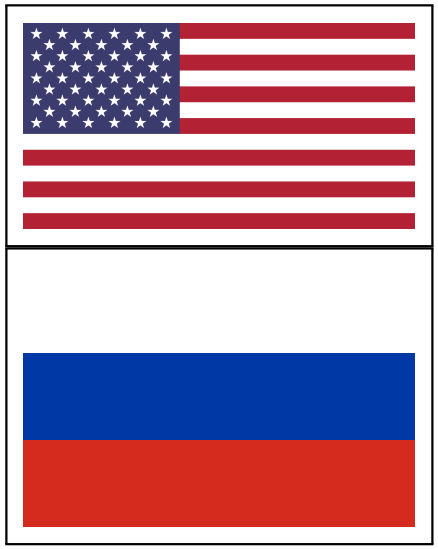

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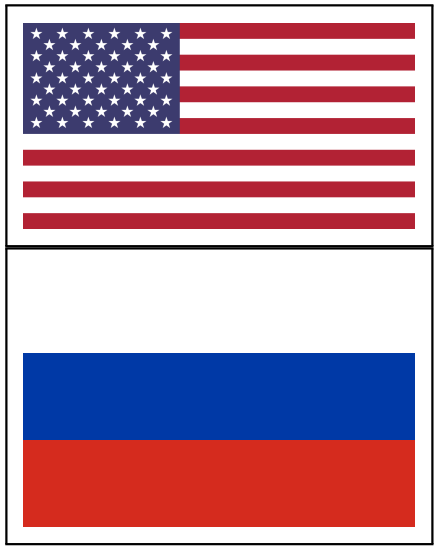

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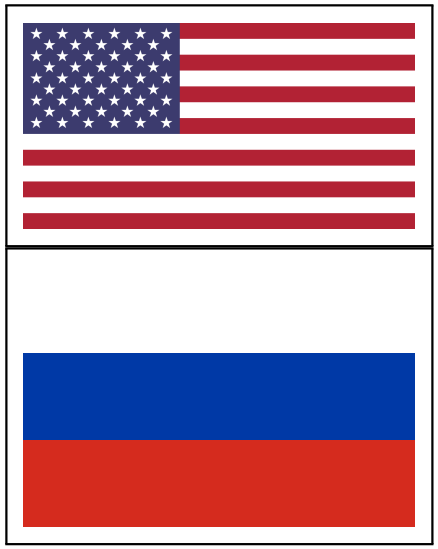

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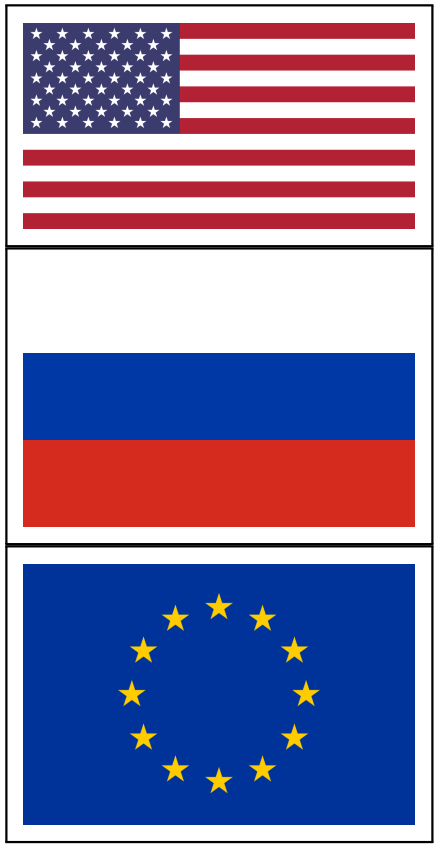

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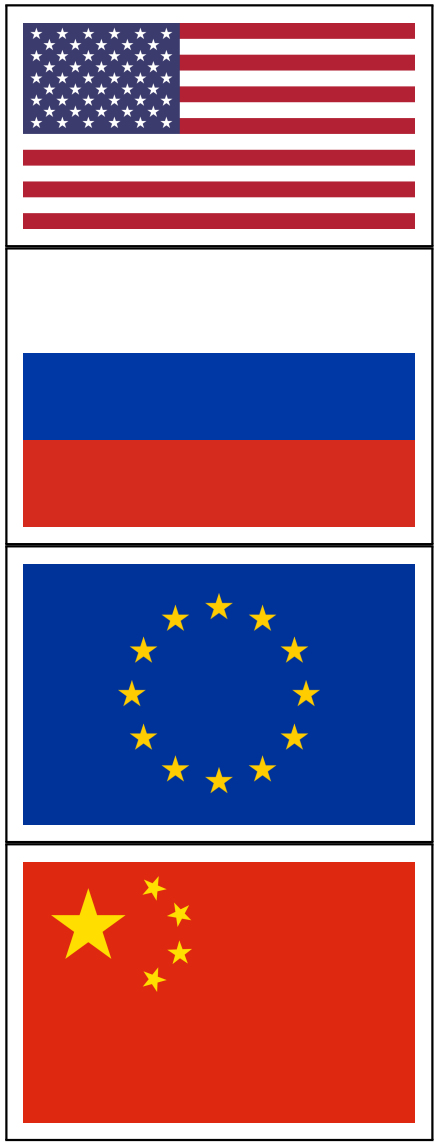

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China: BeiDou
Nominal constellation of 27 MEO satellites
Signals on 3 frequencies

Range of GNSS–Signals

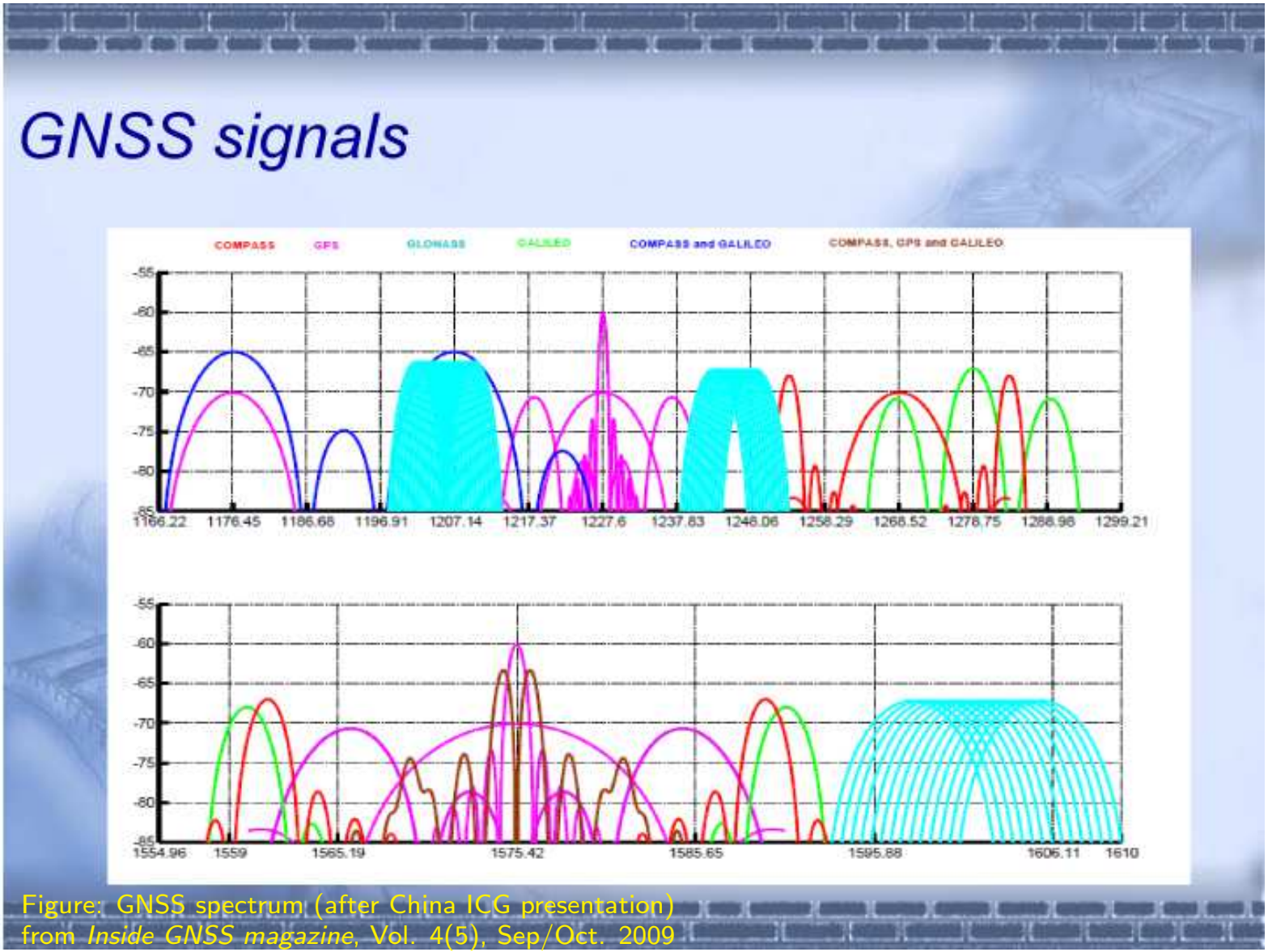

Figure: GNSS spectrum (after China ICG presentation) from *Inside GNSS magazine*, Vol. 4(5), Sep/Oct. 2009

IGS–MGEX campaign

- **IGS–MGEX: IGS Multi–GNSS Experiment**

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- **August 2011: Call for Participation**:
  This Call for Participation for the IGS Multi-GNSS Experiment — IGS M-GEX — recognizes the availability of new additional GNSS signals and new constellations on the horizon. The IGS is preparing for this next phase in the evolution of the IGS to eventually generate products for all GNSS available.

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  - upcoming new systems **Galileo, BeiDou**
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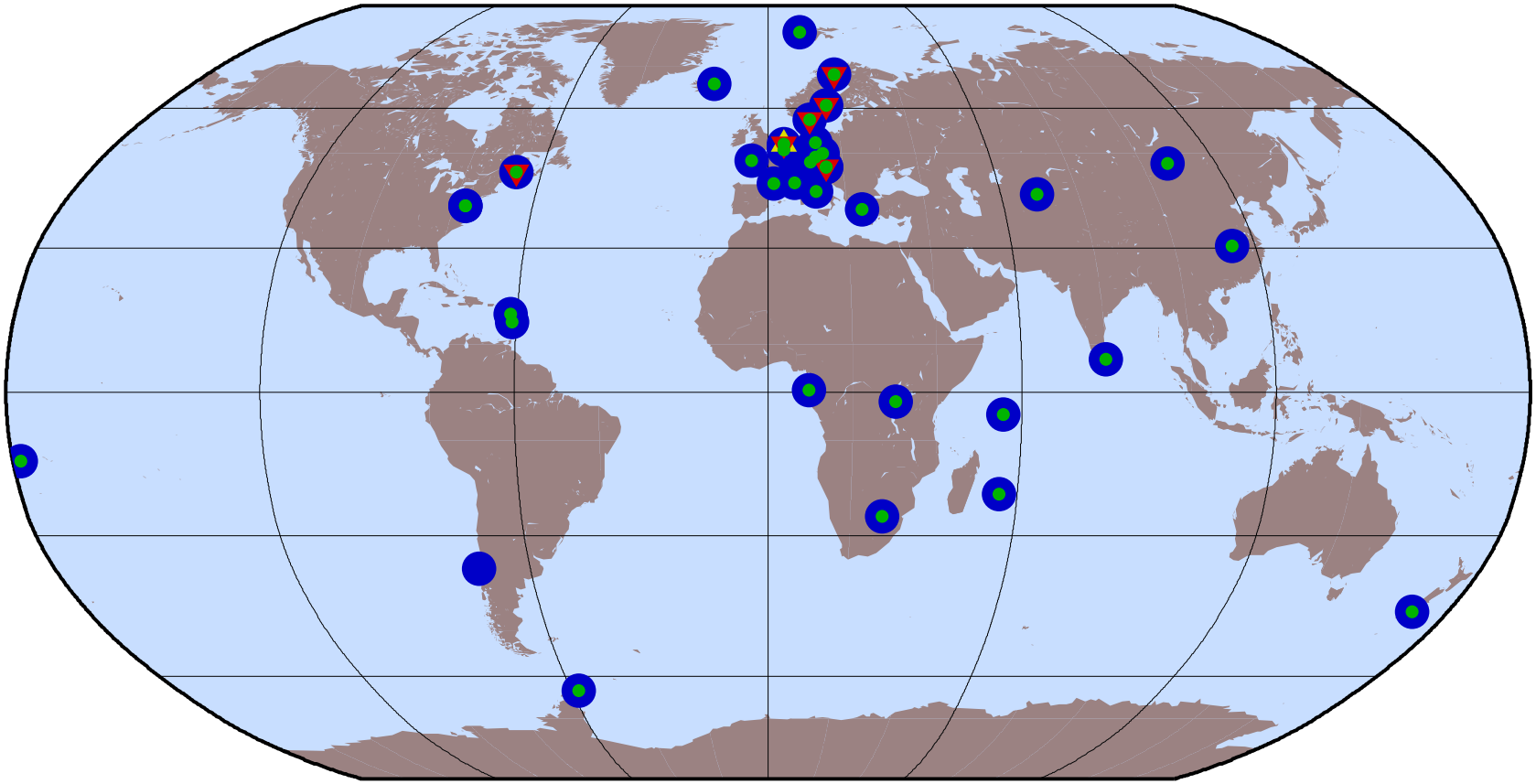
Development of the IGS–MGEX network



Tracking status by 2012–JUL–01

- GPS(L5)+Galileo+BeiDou+QZSS (1)
- GPS(L5)+Galileo+QZSS (0)
- (GPS+)QZSS (0)
- GPS(L5)+Galileo+BeiDou (5)
- GPS(L5)+Galileo (29)
- GPS(L5) (2)

Extracted from available RINEX 3 observations files

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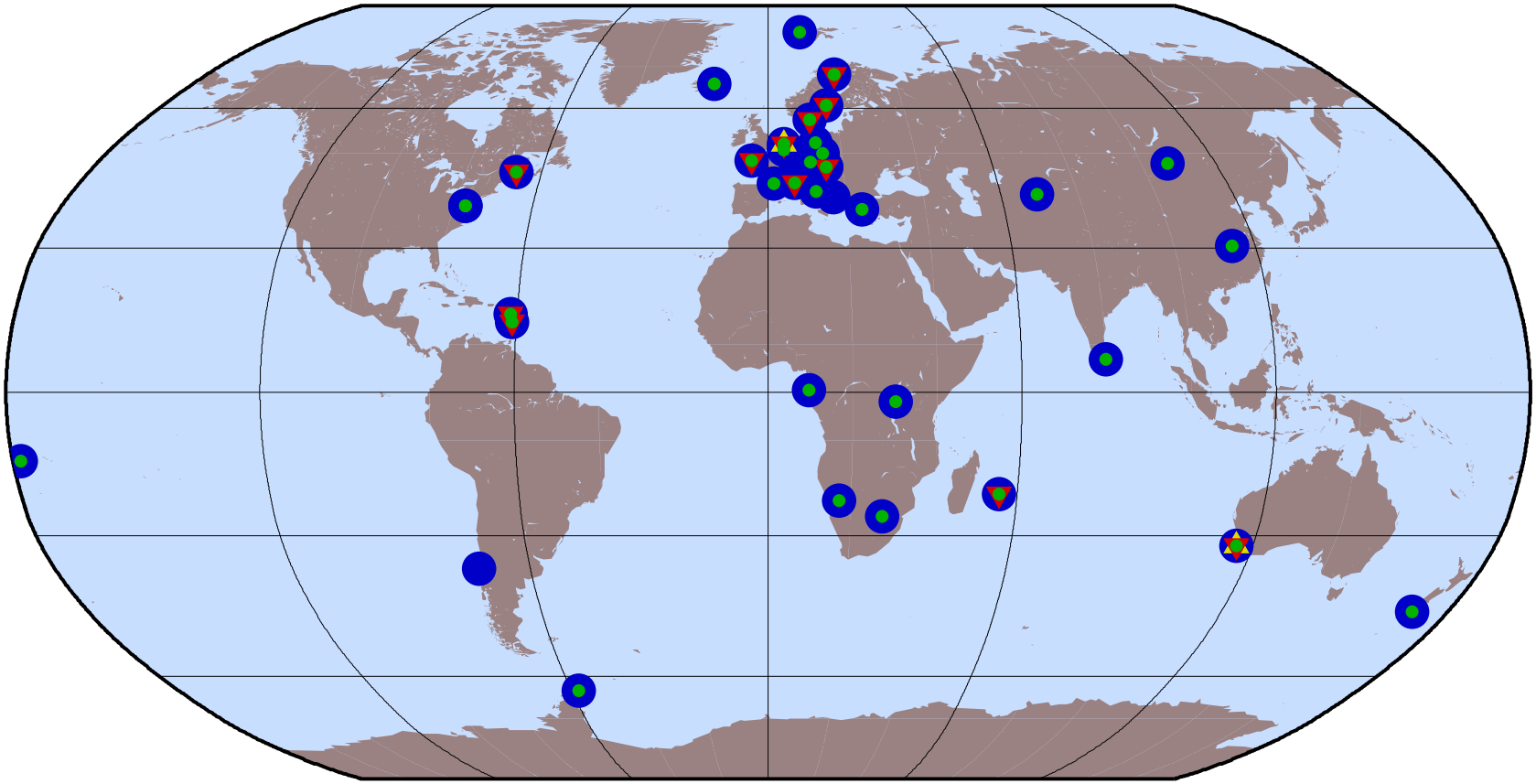

Tracking status by 2012−AUG−20

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- (GPS+)QZSS (0)
- GPS(L5)+Galileo+BeiDou (10)
- GPS(L5)+Galileo (22)
- GPS(L5) (6)

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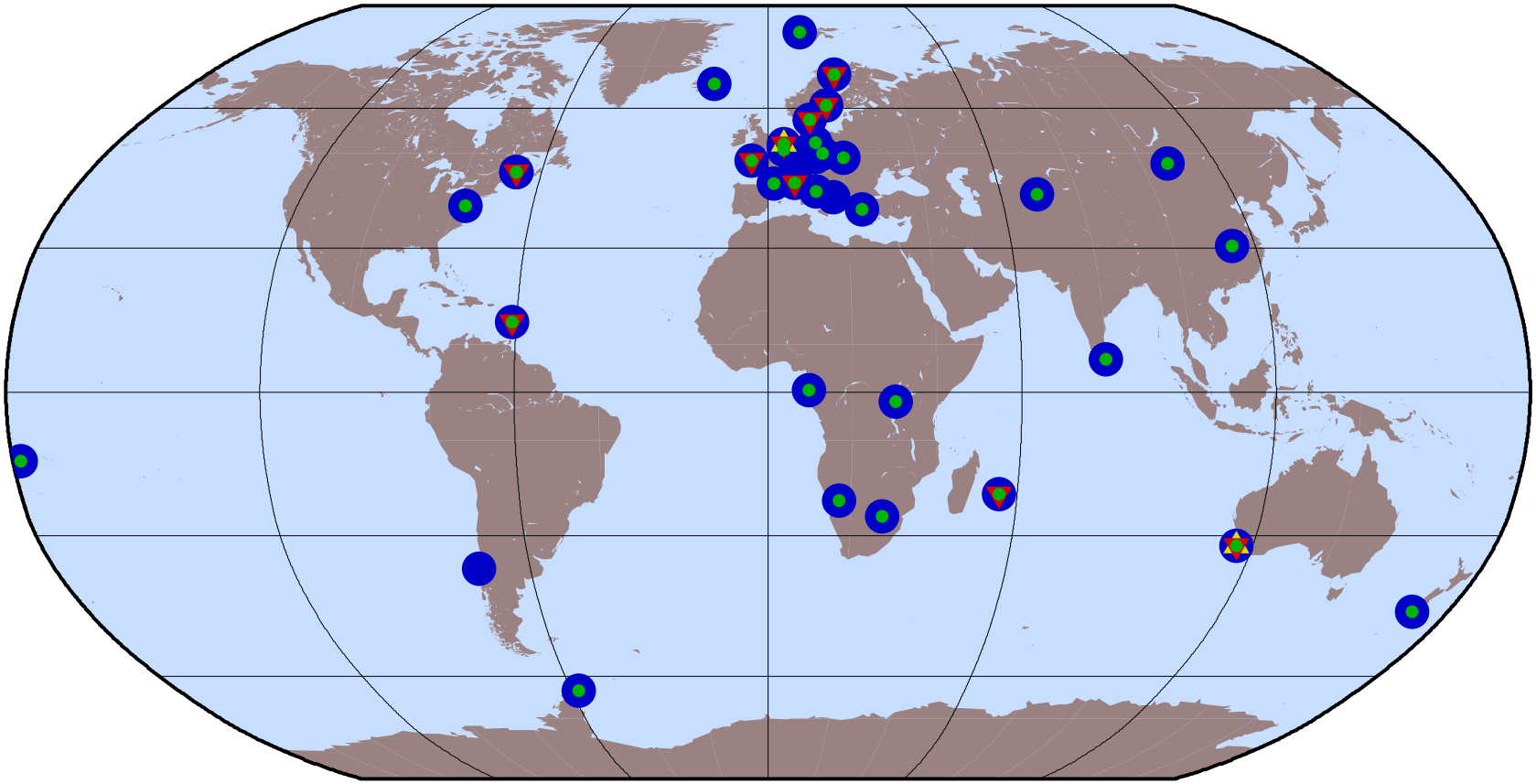

Tracking status by 2012–OCT–09

- GPS(L5)+Galileo+BeiDou+QZSS (2)
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- (GPS+)QZSS (0)
- GPS(L5)+Galileo+BeiDou (9)
- GPS(L5)+Galileo (21)
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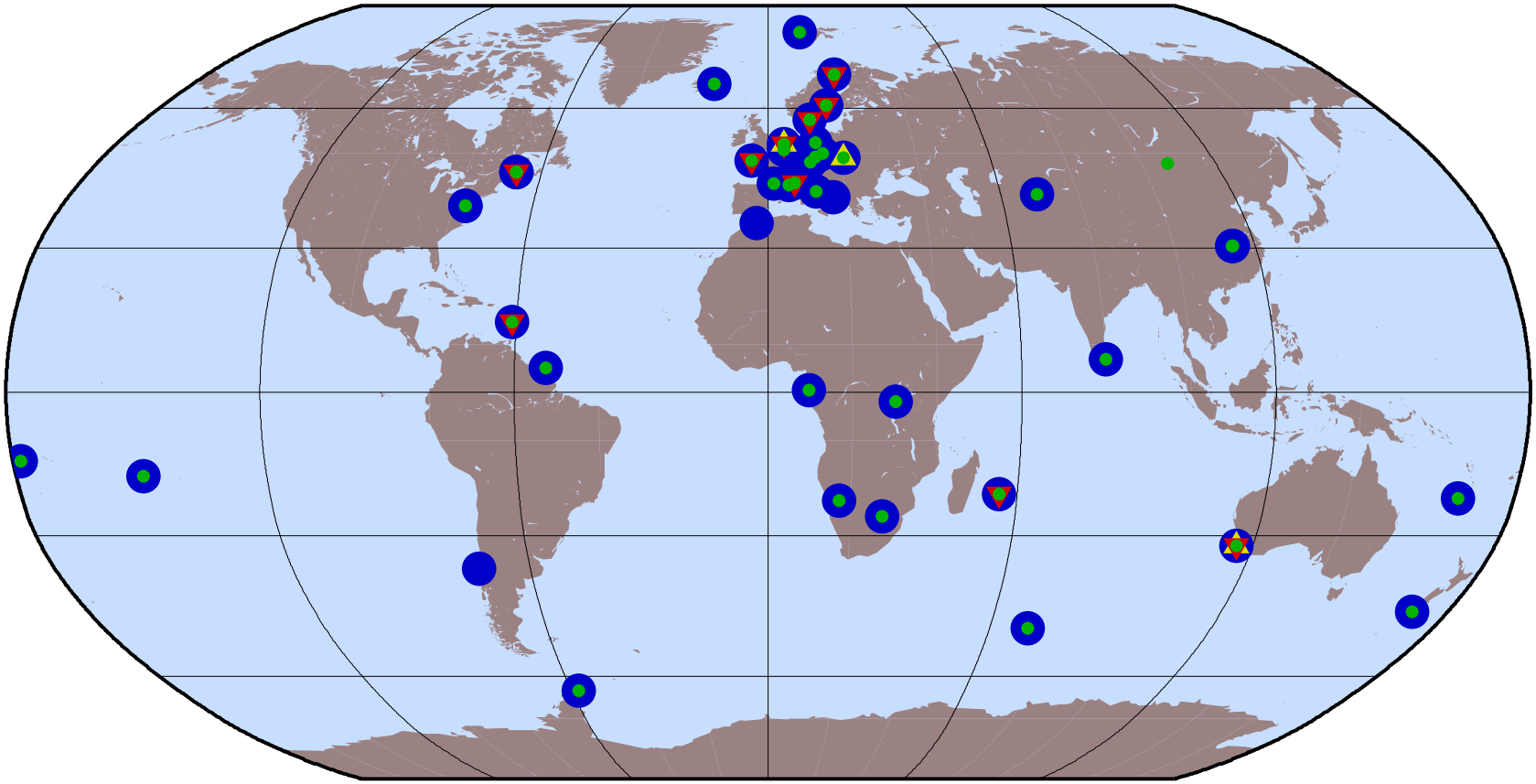

Tracking status by 2012–NOV–28

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- GPS(L5)+Galileo (27)
- GPS(L5) (5)

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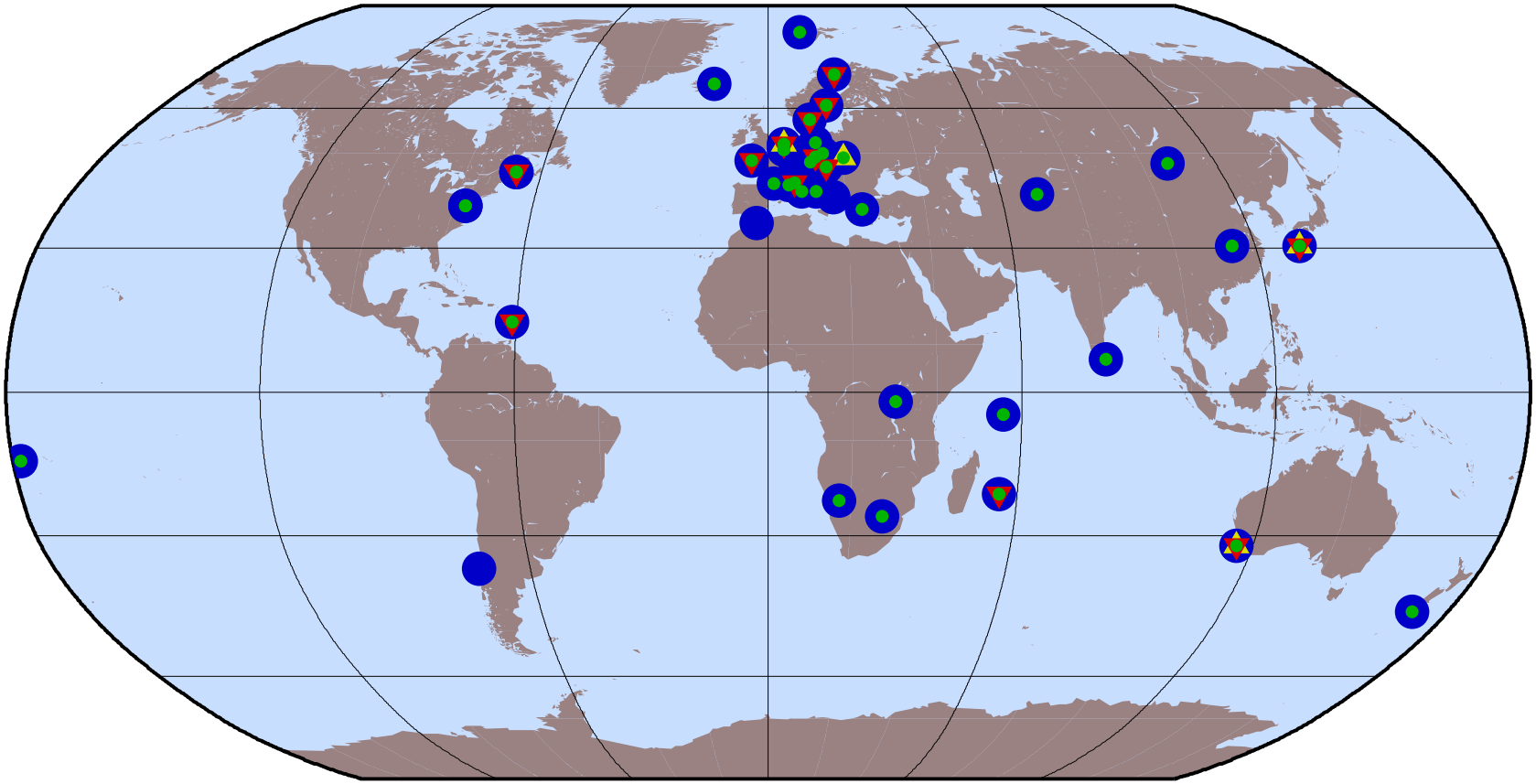

Tracking status by 2013−JAN−17

- GPS(L5)+Galileo+BeiDou+QZSS (3)
- GPS(L5)+Galileo+BeiDou (11)
- GPS(L5)+Galileo+QZSS (1)
- GPS(L5)+Galileo (23)
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- GPS(L5) (5)

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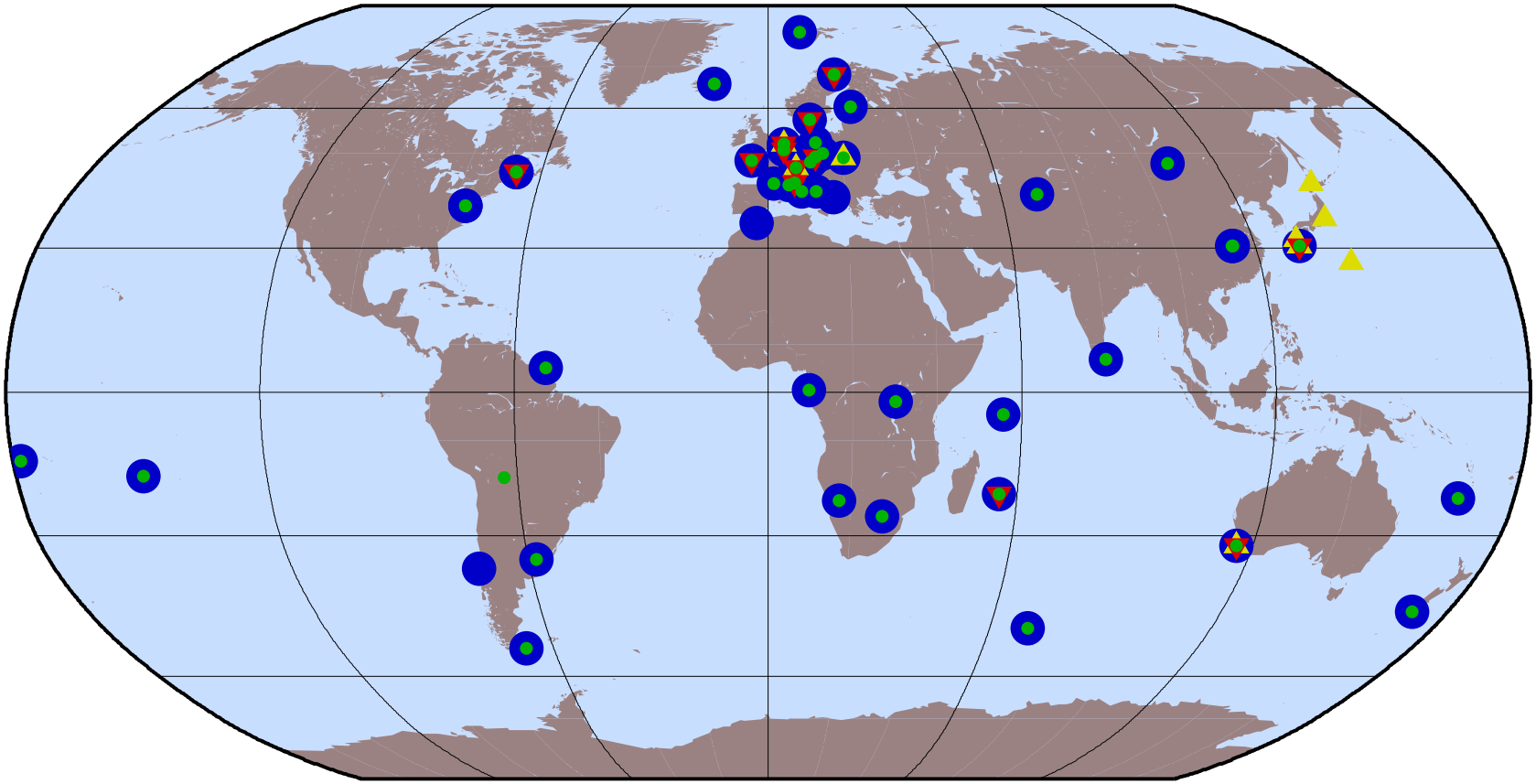

Tracking status by 2013–MAR–08

- GPS(L5)+Galileo+BeiDou+QZSS (4)
- GPS(L5)+Galileo+QZSS (1)
- (GPS+)QZSS (4)
- GPS(L5)+Galileo+BeiDou (9)
- GPS(L5)+Galileo (30)
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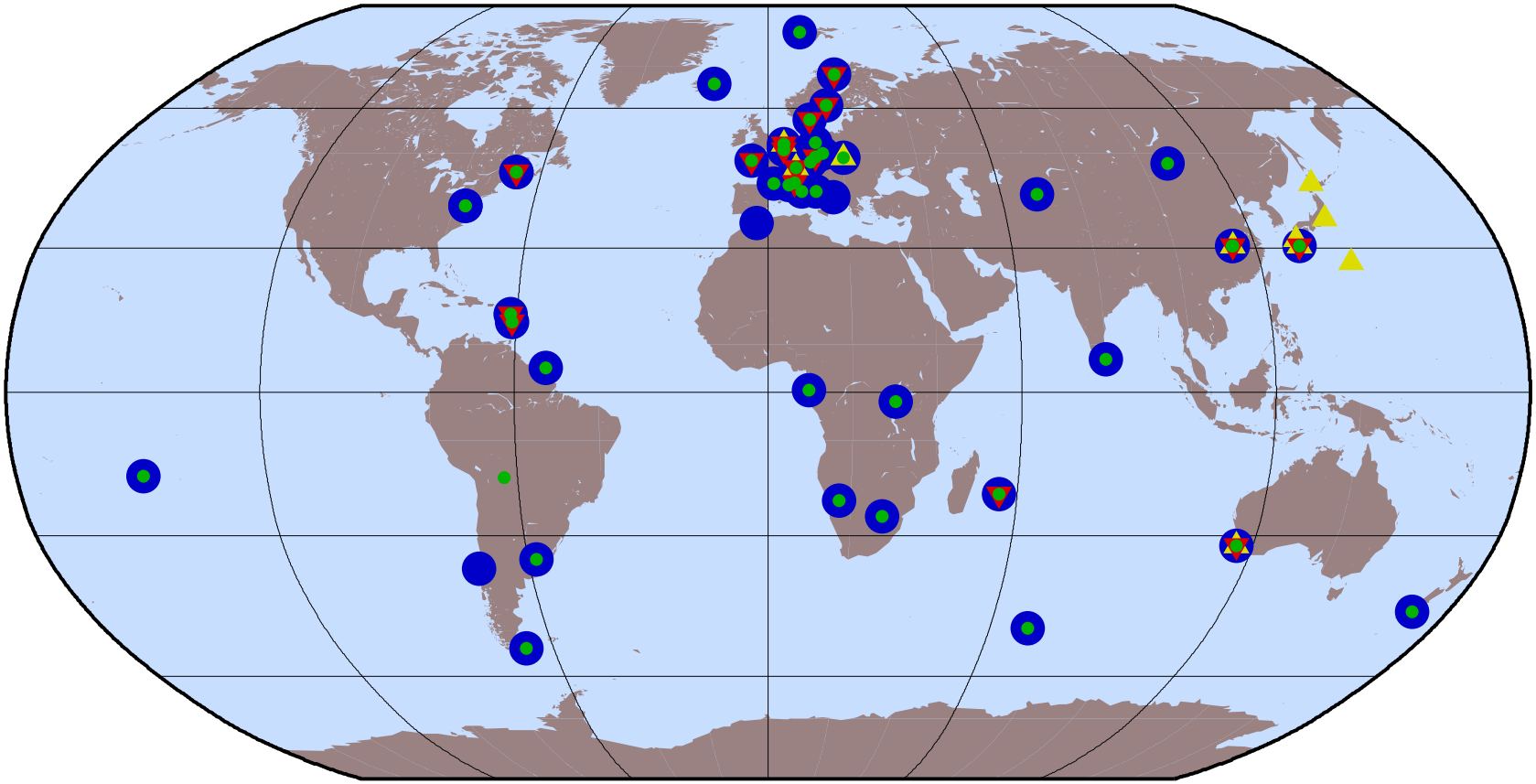

Tracking status by 2013−APR−02

- GPS(L5)+Galileo+BeiDou+QZSS (5)
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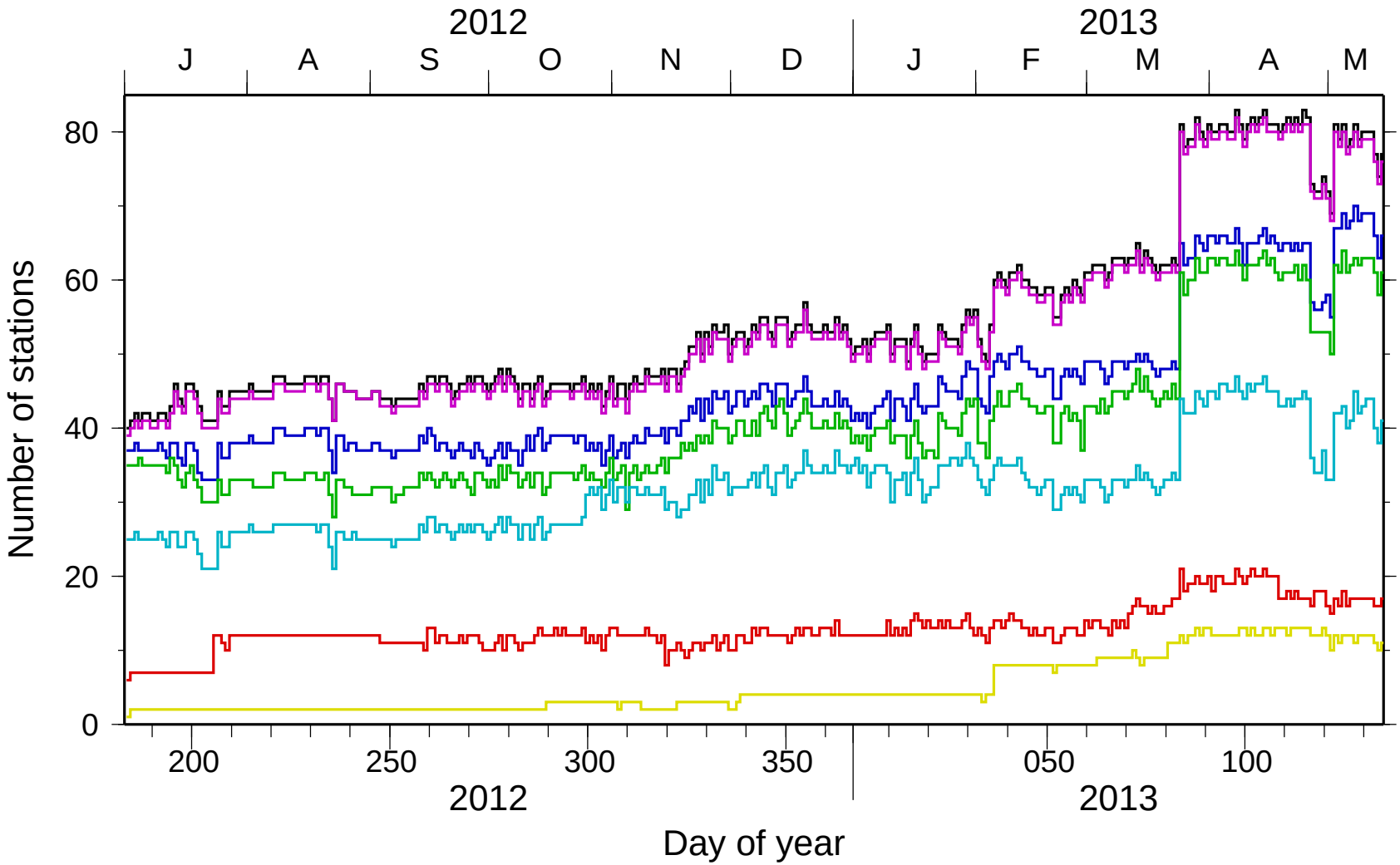
- (GPS+)QZSS (4)
- GPS(L5)+Galileo+BeiDou (15)
- GPS(L5)+Galileo (38)
- GPS(L5) (4)

Extracted from available RINEX 3 observations files

Development of the IGS–MGEX network



Solutions in the frame of IGS–MGEX

Institution	Constellations	Availability (week/day)
CNES/CLS	Galileo	since 1692/1
COD	GPS+GLONASS+Galileo	since 1689/5
GFZ	GPS+Galileo	1680/0-1683/6
TUM	Galileo&QZSS	since 1711/1

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3. COD–solution is for political reasons only available on an non–operational basis.

CODE–Contribution to IGS MGEX

The CODE analysis center

- CODE, Center for Orbit Determination in Europe, is one of at present ten Analysis Centers of the IGS. CODE is formed as a joint venture of
  - the Astronomical Institute of the University of Bern (AIUB),
  - the Swiss Federal Office of Topography (swisstopo),
  - the Institut für Kartographie und Geodäsie (BKG), and
  - the Institut für Astronomische und Physikalische Geodäsie of TU München (IAPG, TUM).

AIUB

Bundesamt für Kartographie und Geodäsie

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Technische Universität München

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- Initially about 20, today more than 250 stations are processed daily.
  All results are generated using the *Bernese GNSS Software*.
- CODE provides products for the final, rapid, and ultra-rapid IGS products. All of them (except clocks) are based on a fully combined GPS/GLONASS data analysis.
- CODE started with this approach in May 2003.
  Meanwhile all European global analysis centers join this a strategy for their final products: ESOC, GFZ, GRGS, NRCan.

The CODE MGEX–solution

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Product list:	daily orbits (SP3) and ERPs
Distribution:	`ftp://cddis.gsfc.nasa.gov/gnss/products/mgex/`
Timespan covered:	GPS-weeks 1689–1720 (DOY 12/146–12/364)

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Processing scheme:	double-difference network processing
Orbit characteristic:	3-day long arcs

Why multi–day arcs?

Number of observations per satellite and day, 15 minutes sampling

Date	E11	E12	E19	E20	
2012-DEC-15	1702	1613	1877	1693	
2012-DEC-16	2015	1946	2032	2039	
2012-DEC-17	1938	2011	1766	1929	
2012-DEC-18	1604	1680	1694	1593	
2012-DEC-19	1949	1809	2039	1973	
2012-DEC-20	2010	2023	1934	2025	
2012-DEC-21	1681	1835	1594	1658	
2012-DEC-22	1798	1640	1963	1794	
2012-DEC-23	2026	1999	2028	2034	
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Remark:
The same set of (Galileo–capable) tracking stations is used for each of these days/satellites.

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2012-DEC-18	1604	1680	1694	1593	1796	1842	1826	1811
2012-DEC-19	1949	1809	2039	1973	1798	1843	1832	1815
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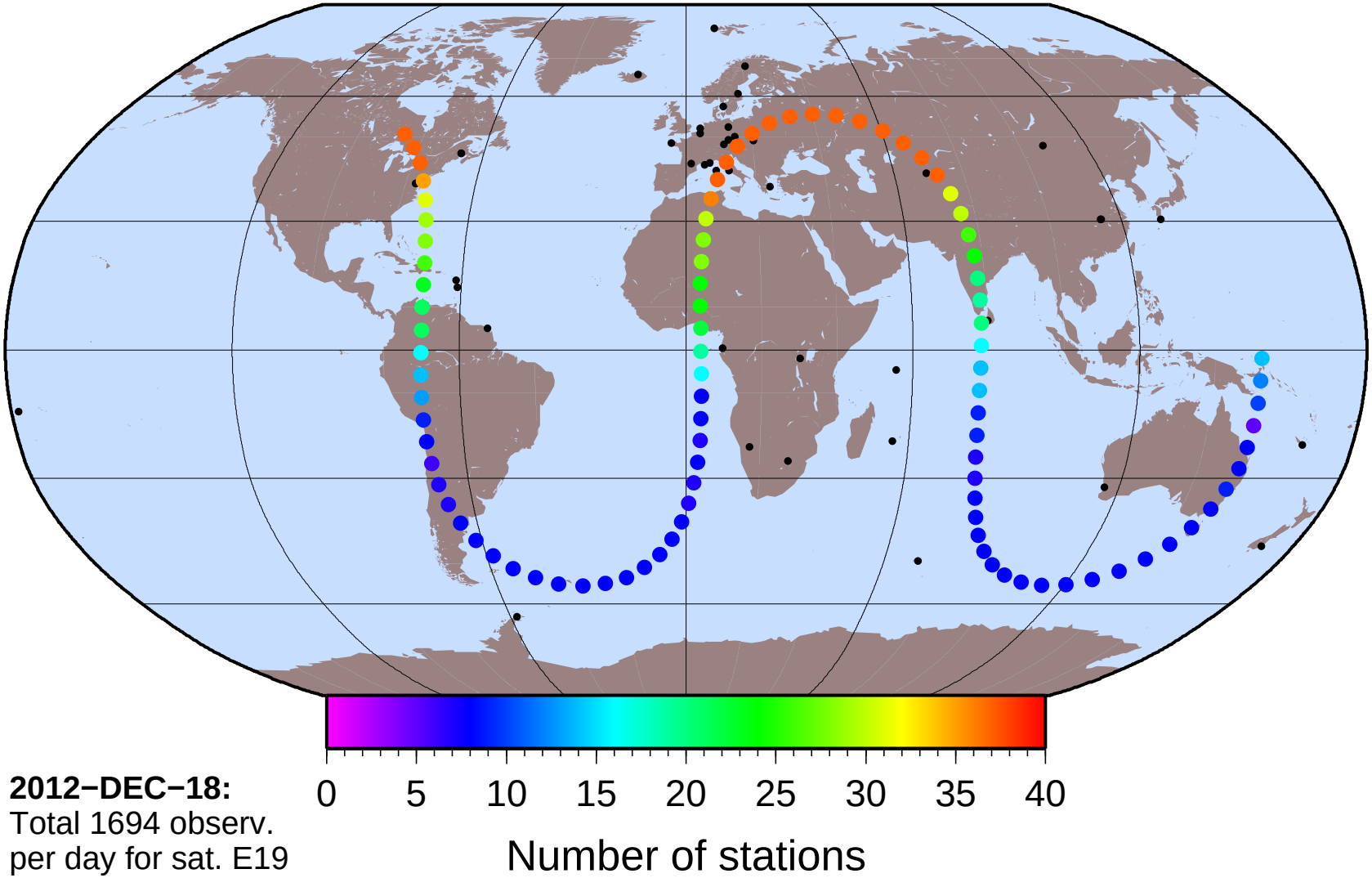
Why multi–day arcs?

Number of stations simultaneously tracking the satellite E19



2012–DEC–18:
Total 1694 observ.
per day for sat. E19

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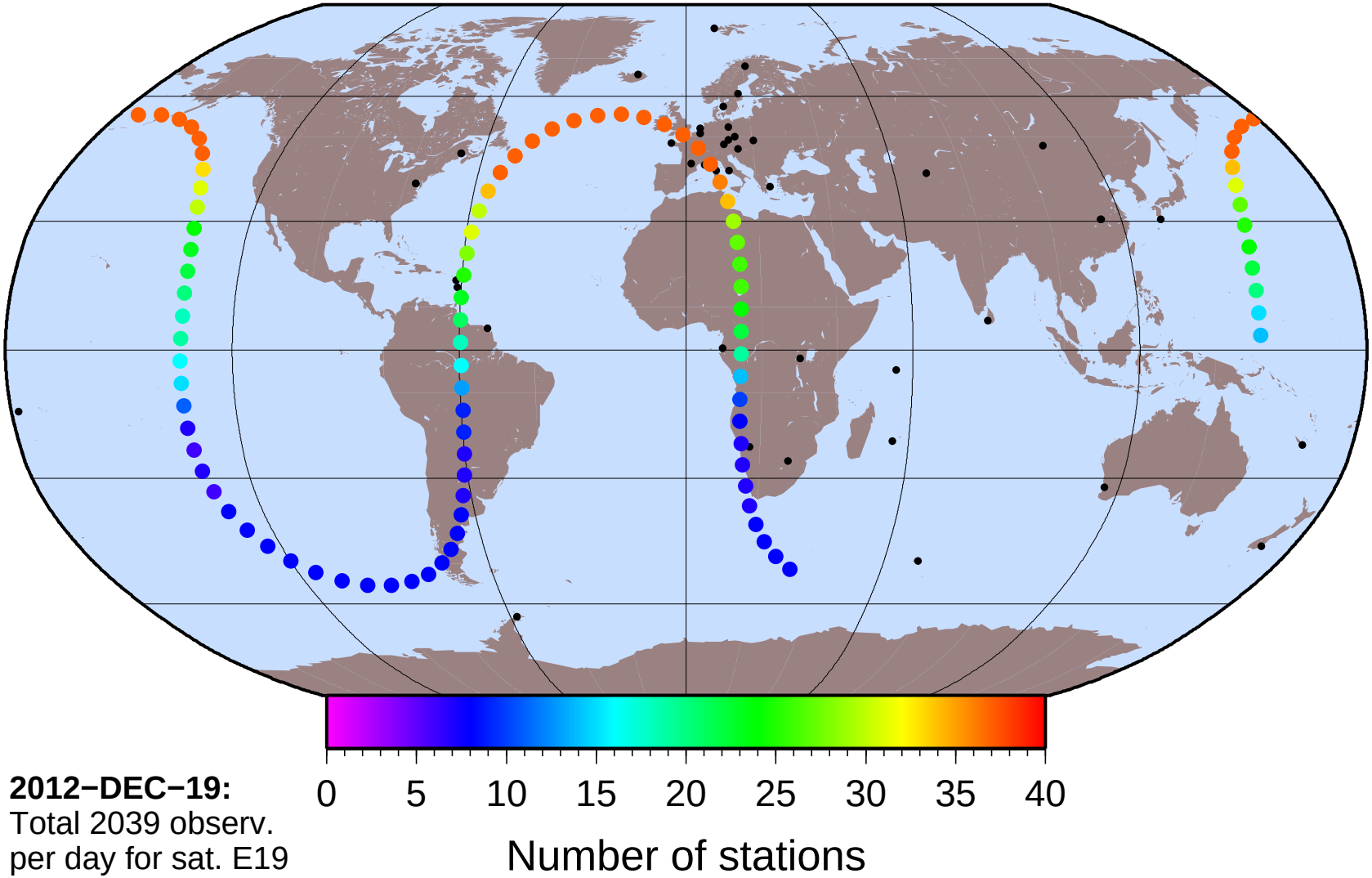

2012–DEC–19:
Total 2039 observ.
per day for sat. E19

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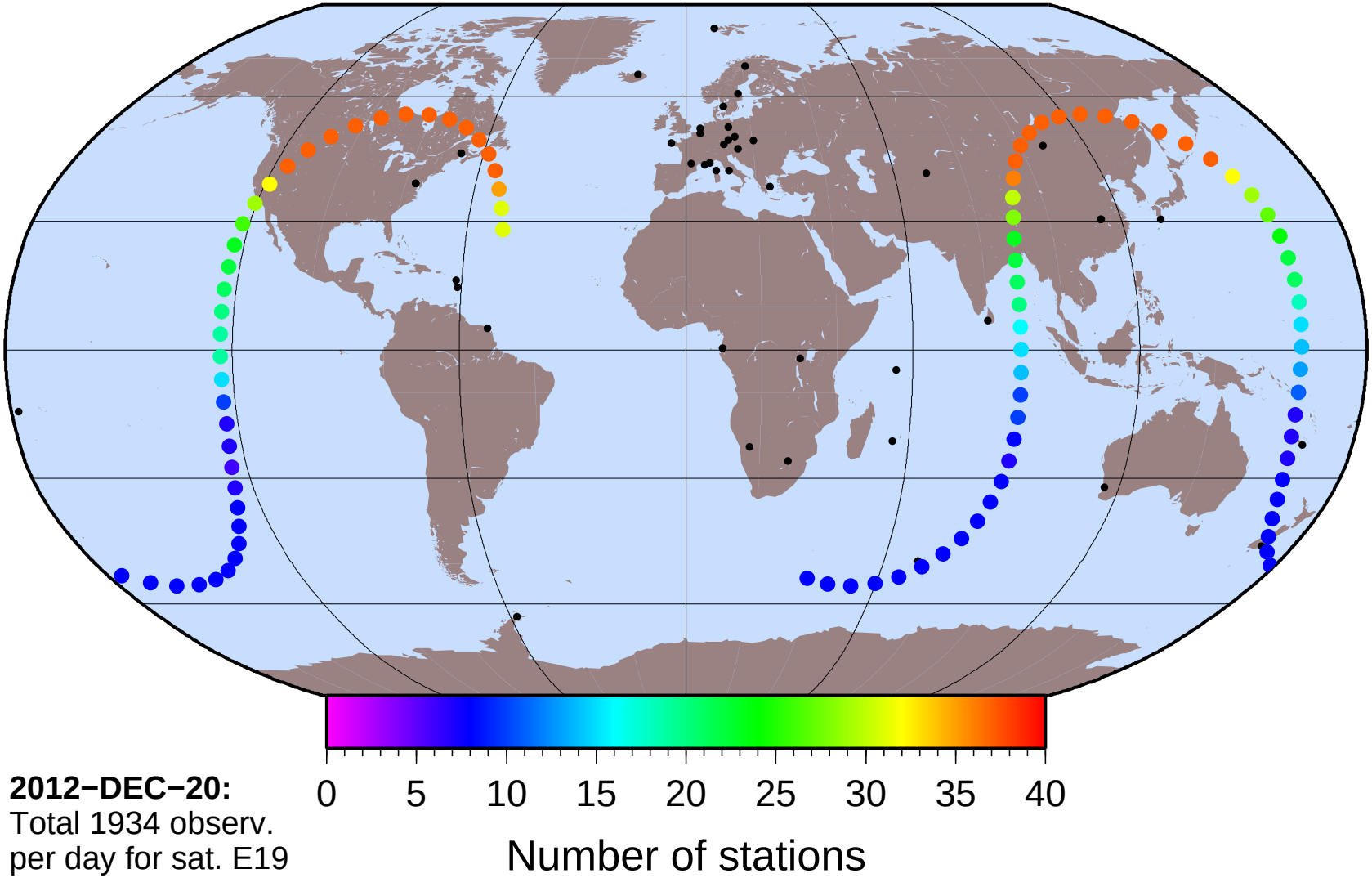
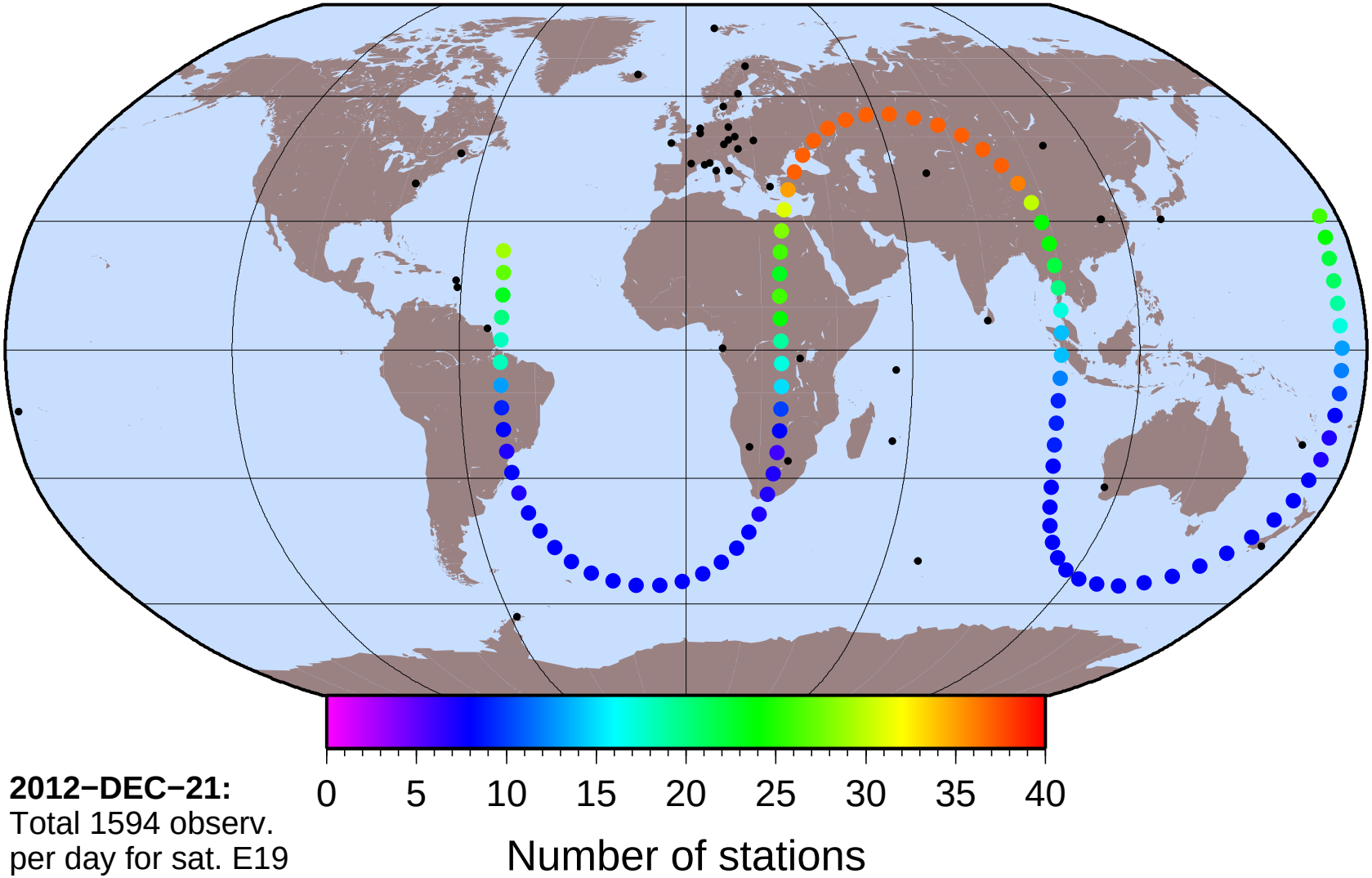
Number of stations simultaneously tracking the satellite E19



2012–DEC–20:
Total 1934 observ.
per day for sat. E19

Why multi–day arcs?

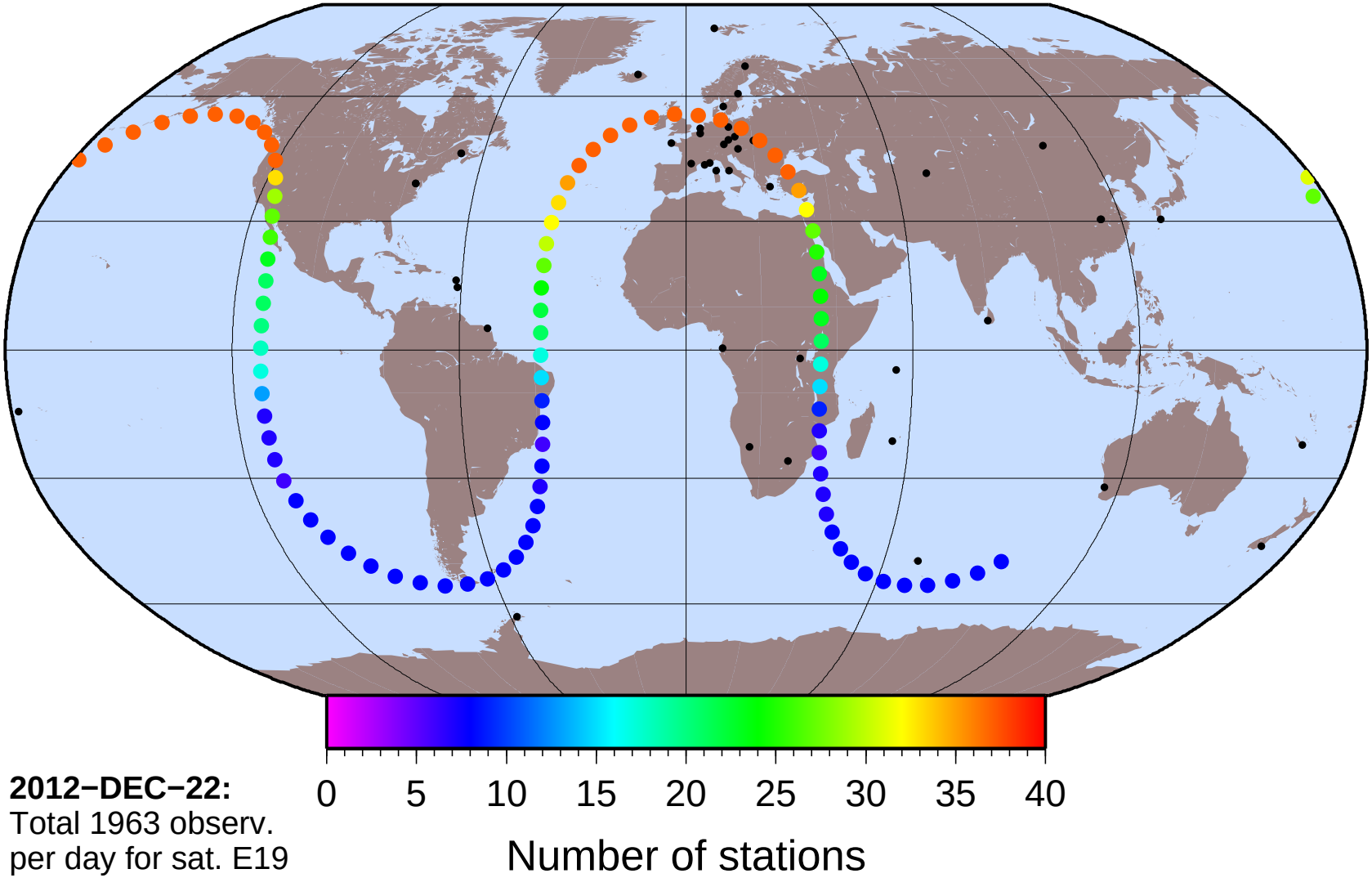
Number of stations simultaneously tracking the satellite E19



2012–DEC–21:
Total 1594 observ.
per day for sat. E19

Why multi–day arcs?

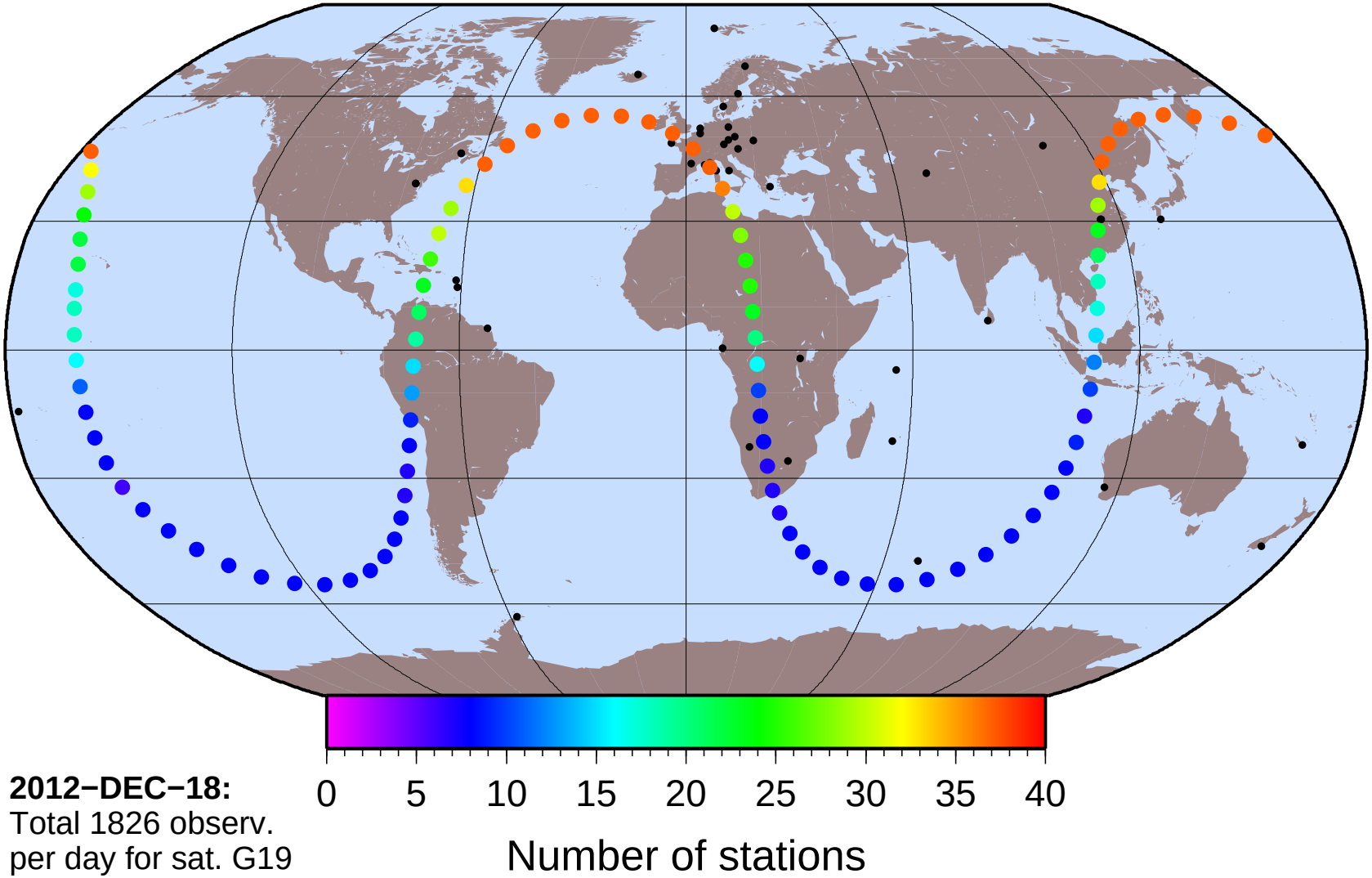
Number of stations simultaneously tracking the satellite E19



2012–DEC–22:
Total 1963 observ.
per day for sat. E19

Why multi–day arcs?

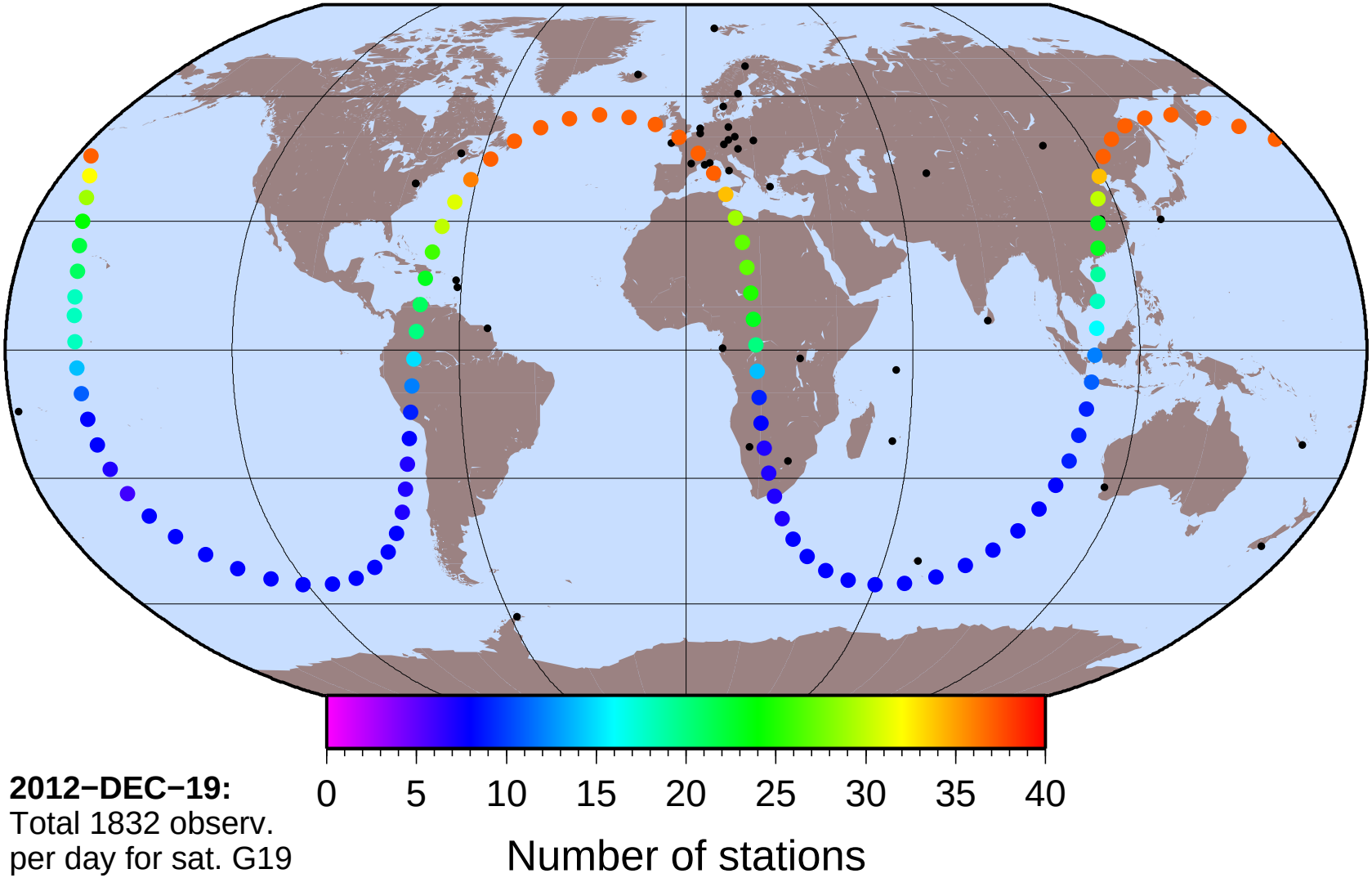
Number of stations simultaneously tracking the satellite G19



2012–DEC–18:
Total 1826 observ.
per day for sat. G19

Why multi–day arcs?

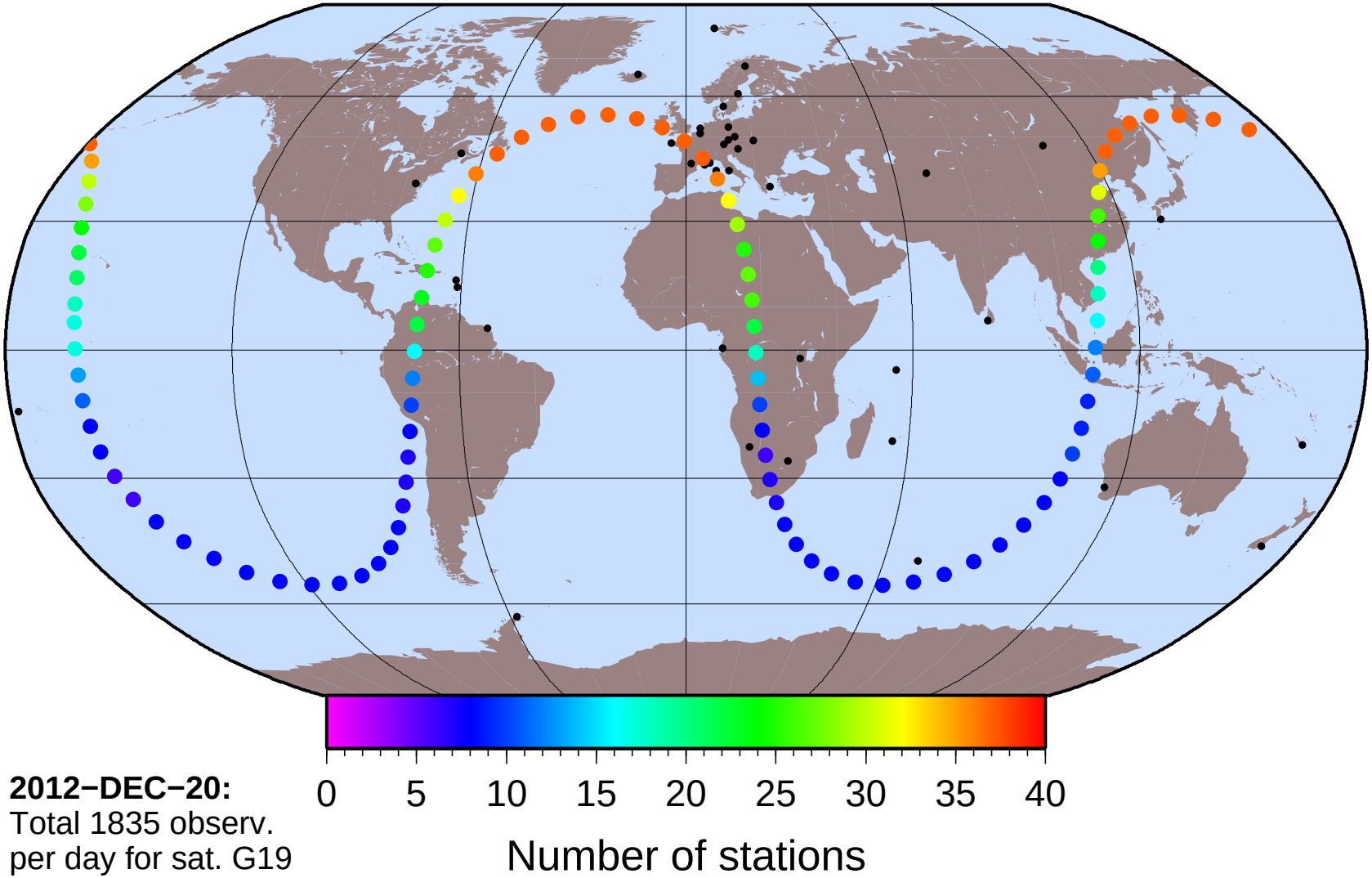
Number of stations simultaneously tracking the satellite G19



2012–DEC–19:
Total 1832 observ.
per day for sat. G19

Why multi–day arcs?

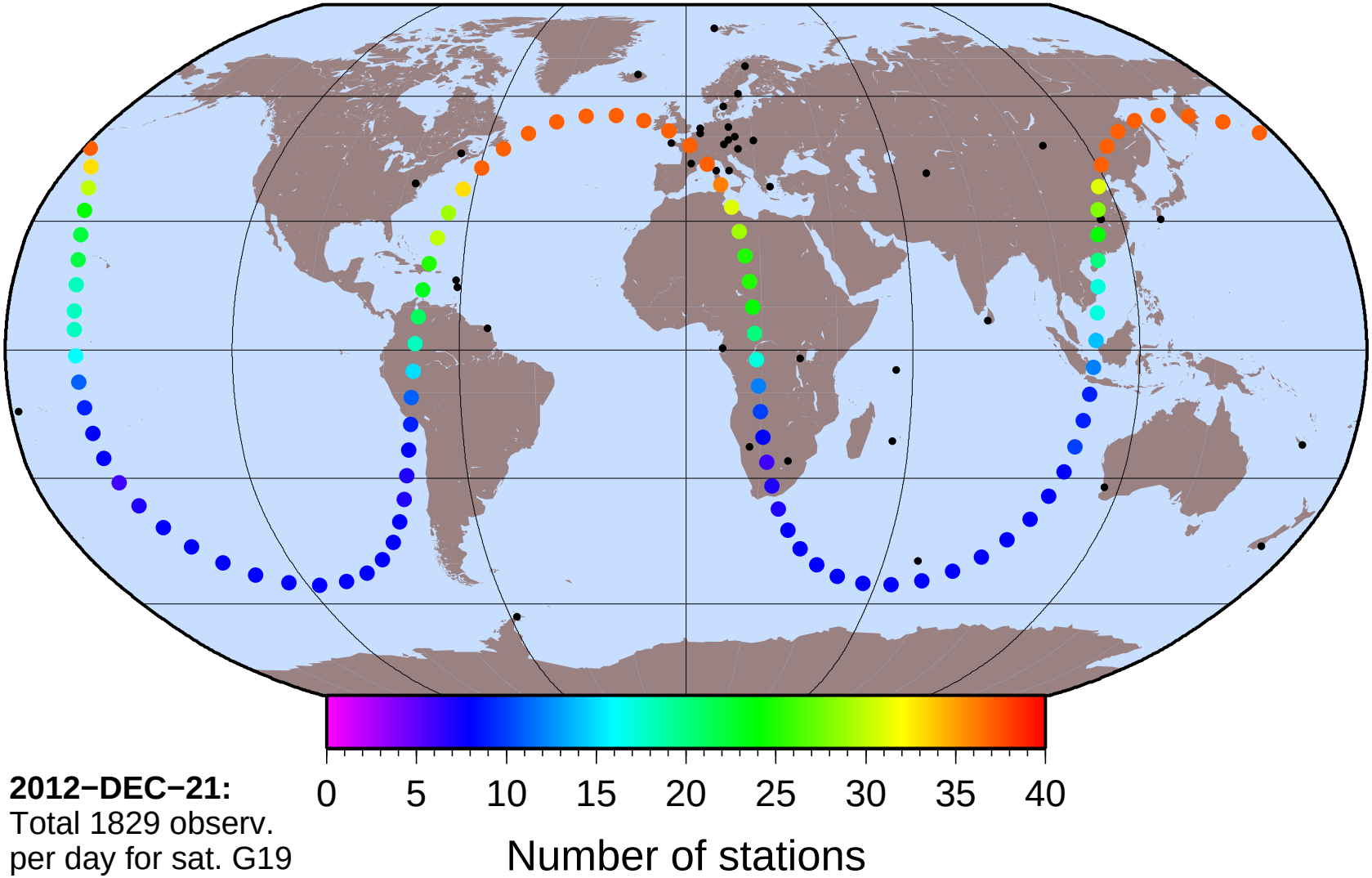
Number of stations simultaneously tracking the satellite G19



2012–DEC–20:
Total 1835 observ.
per day for sat. G19

Why multi–day arcs?

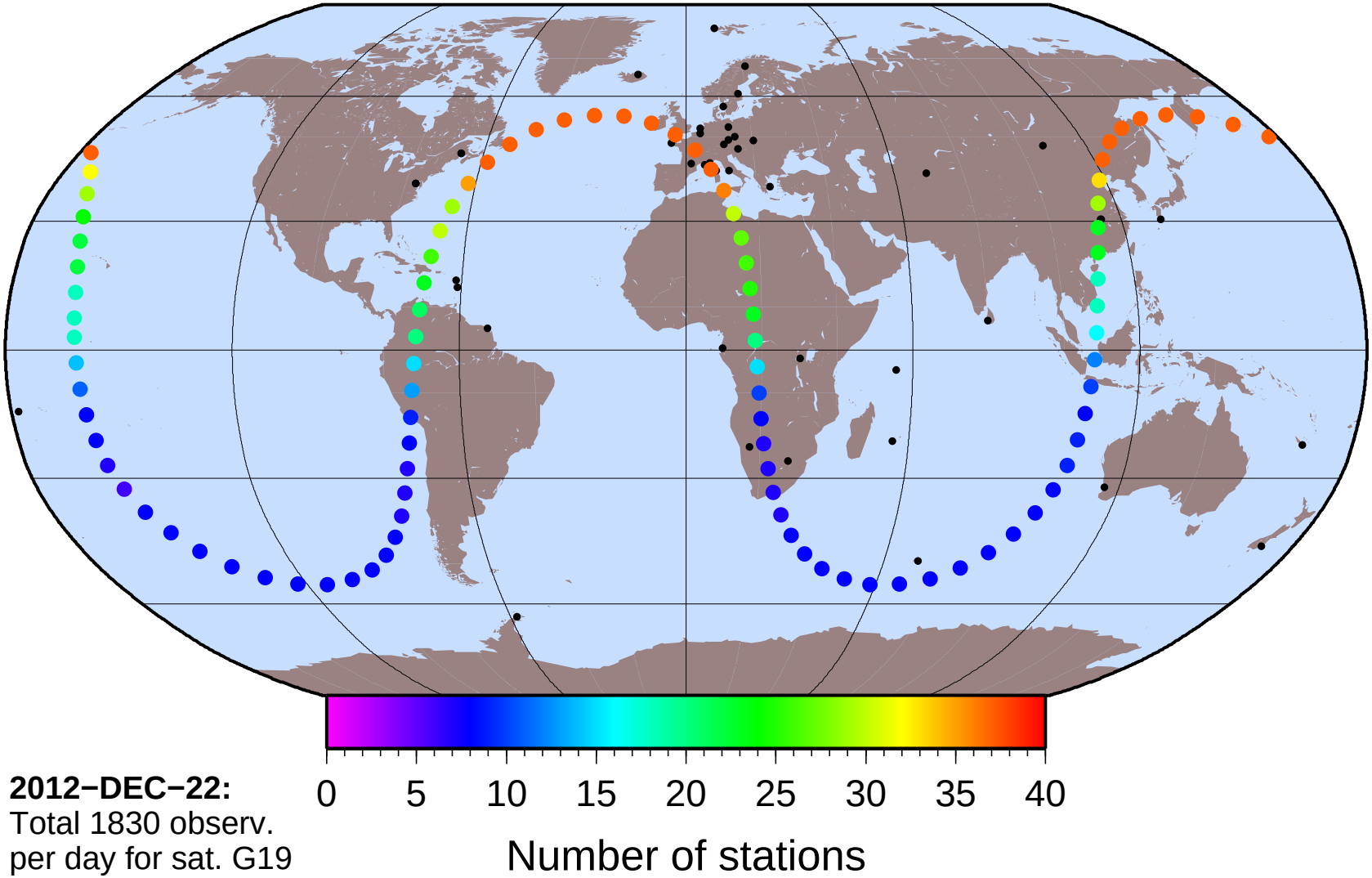
Number of stations simultaneously tracking the satellite G19



2012–DEC–21:
Total 1829 observ.
per day for sat. G19

Why multi–day arcs?

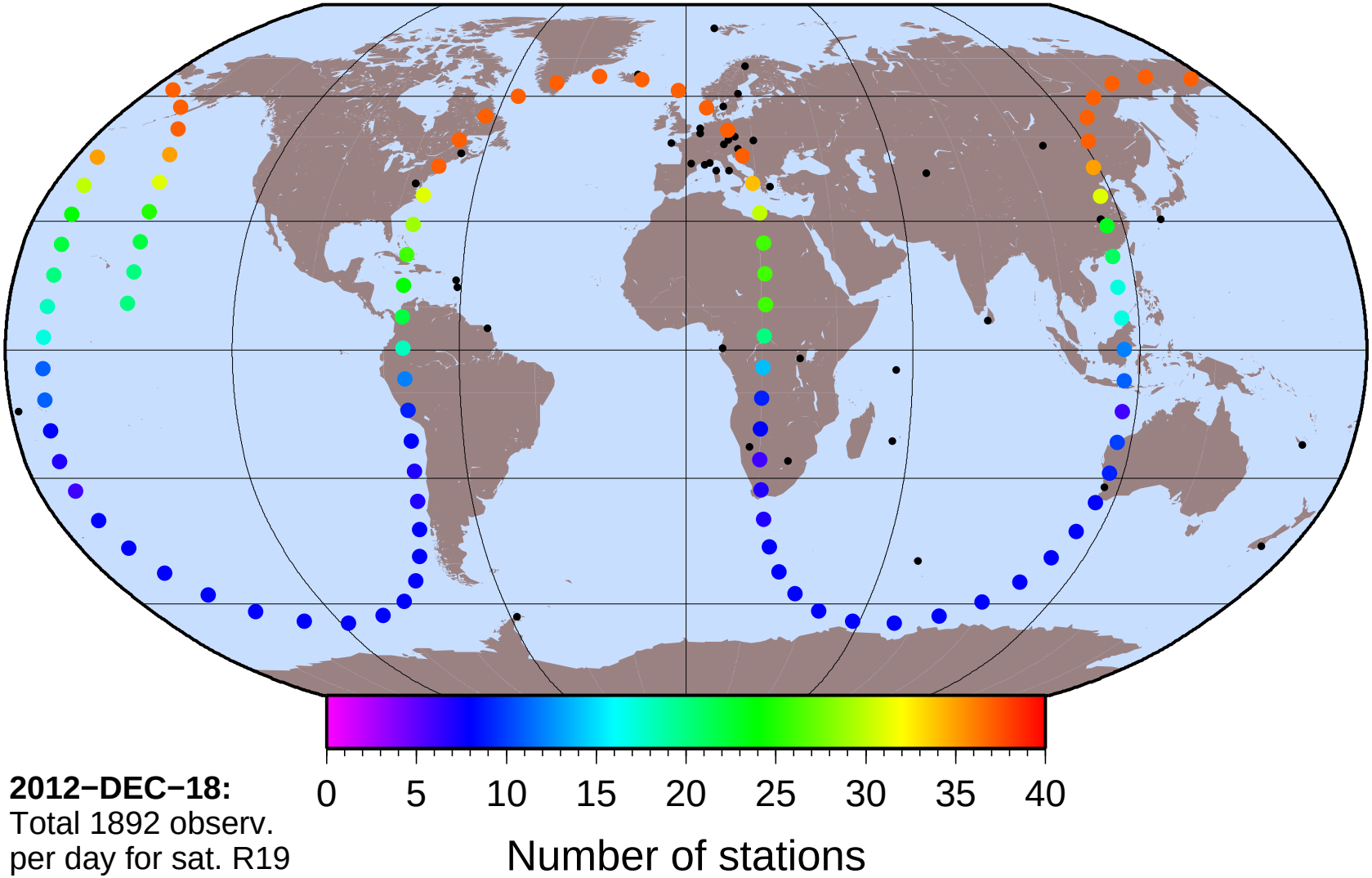
Number of stations simultaneously tracking the satellite G19



2012–DEC–22:
Total 1830 observ.
per day for sat. G19

Why multi–day arcs?

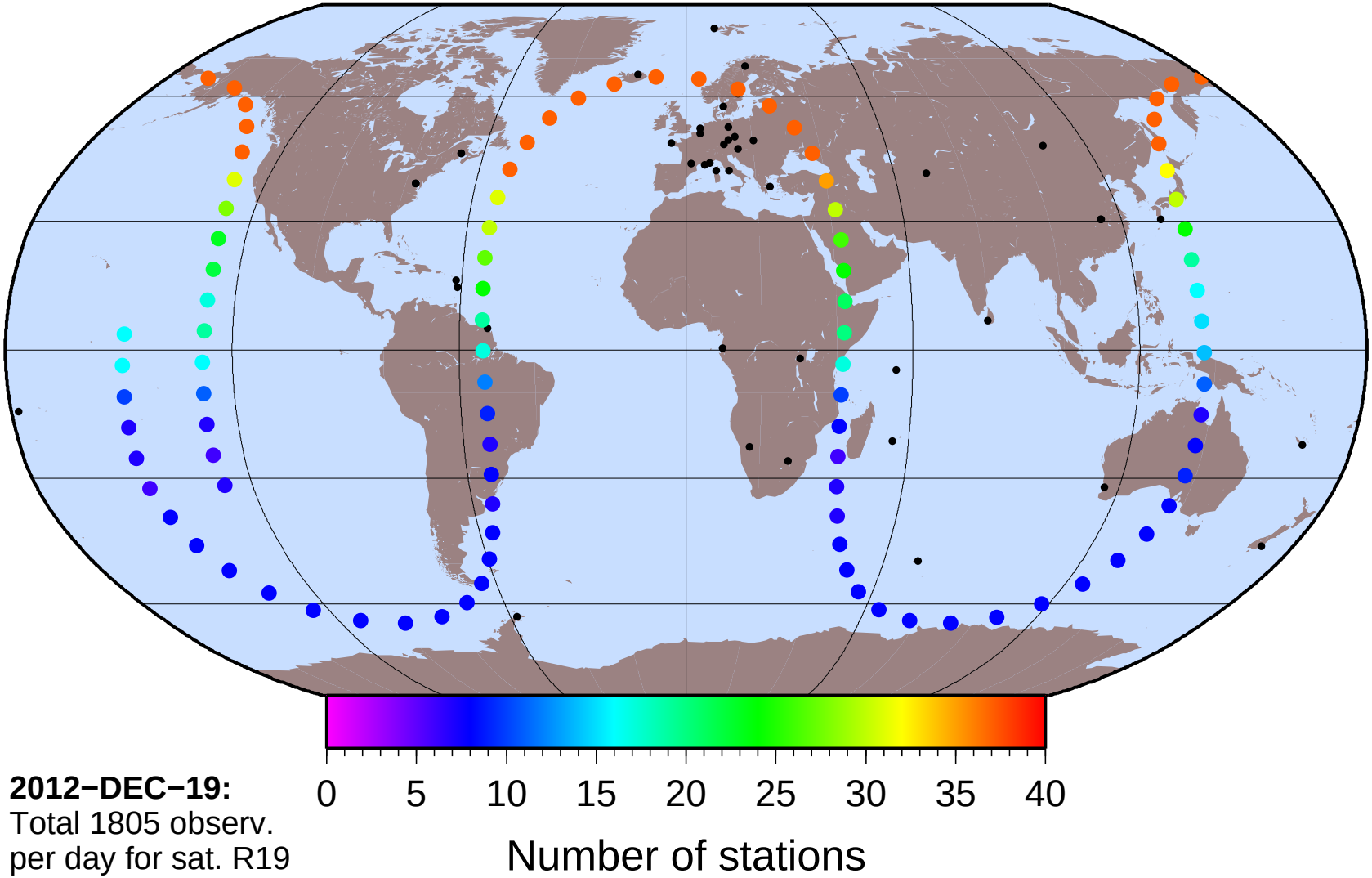
Number of stations simultaneously tracking the satellite R19



2012–DEC–18:
Total 1892 observ.
per day for sat. R19

Why multi–day arcs?

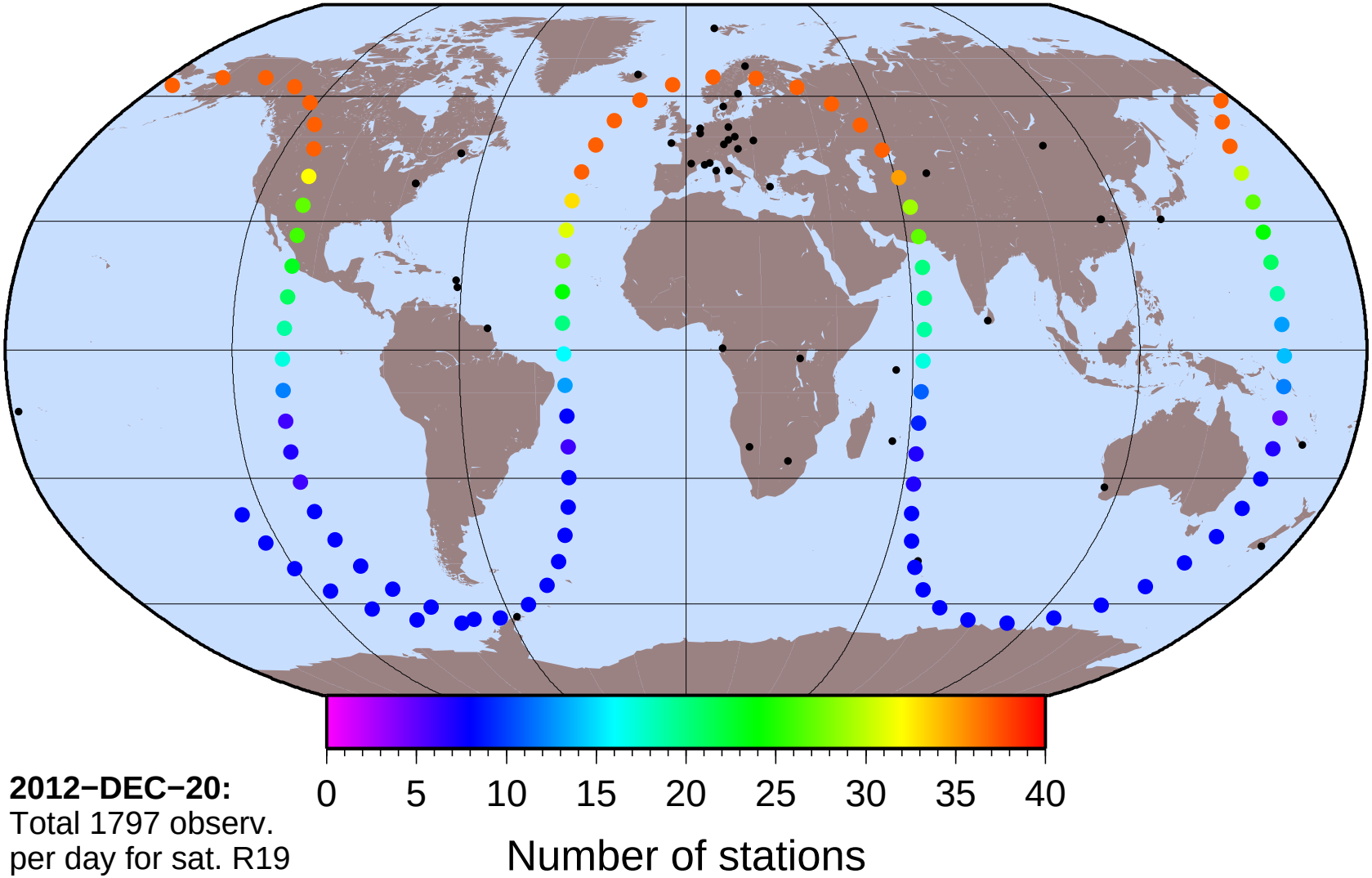
Number of stations simultaneously tracking the satellite R19



2012–DEC–19:
Total 1805 observ.
per day for sat. R19

Why multi–day arcs?

Number of stations simultaneously tracking the satellite R19



2012–DEC–20:
Total 1797 observ.
per day for sat. R19

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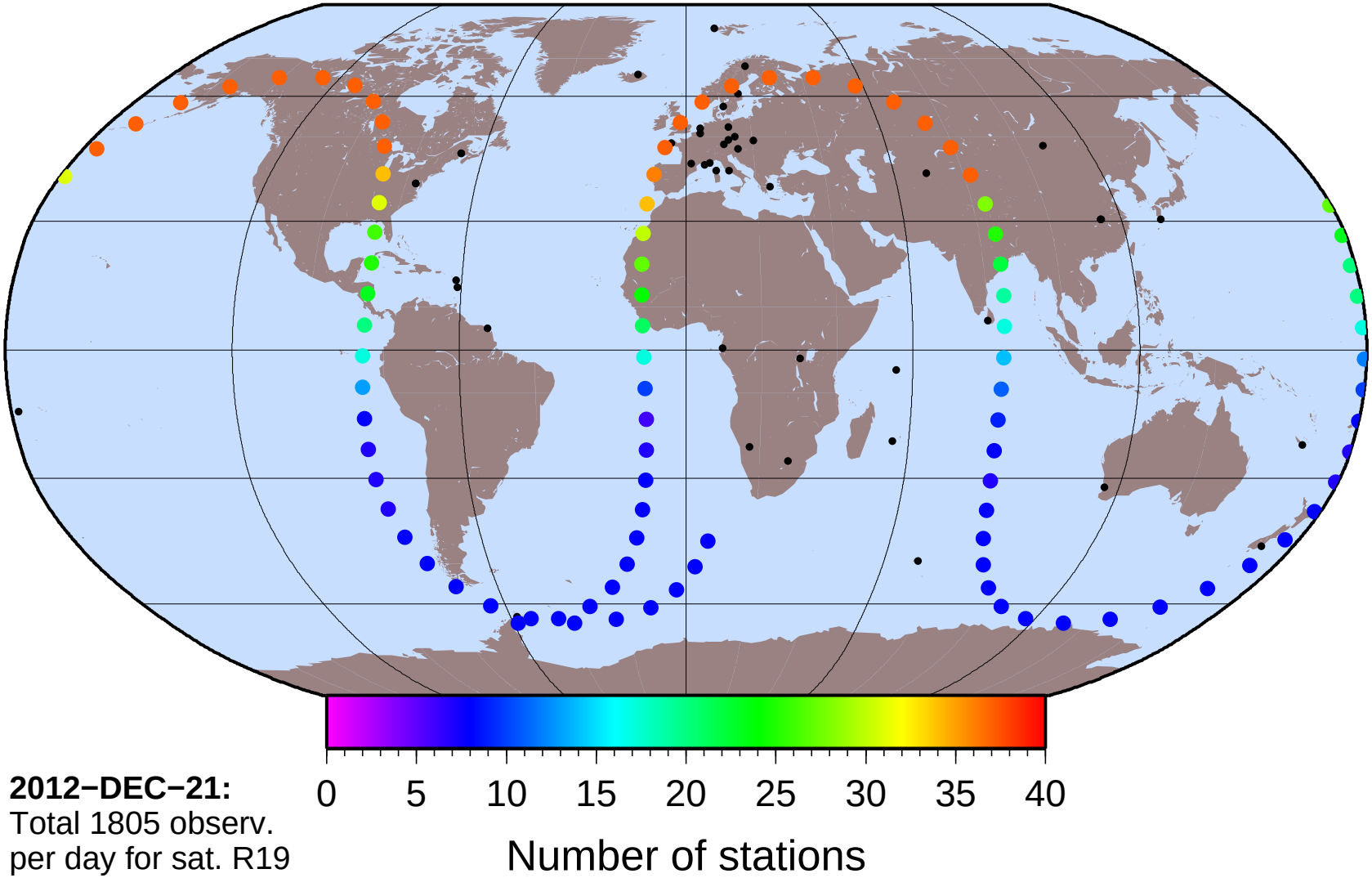
Number of stations simultaneously tracking the satellite R19



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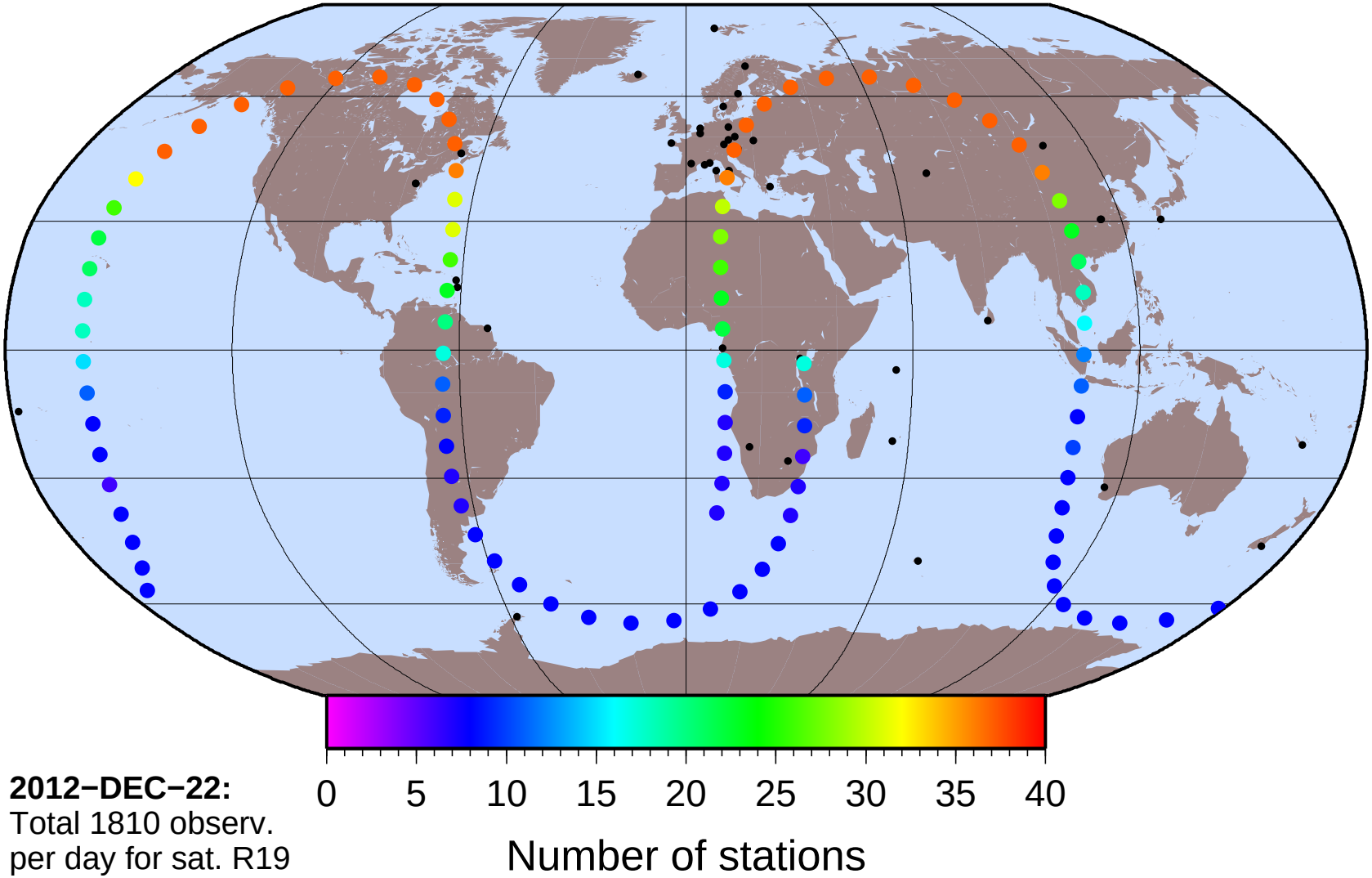

2012–DEC–22:
Total 1810 observ.
per day for sat. R19

Why multi–day arcs?

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Date	E11	E12	E19	E20	G11	G12	G19	G20
2012-DEC-15	1702	1613	1877	1693	1797	1842	1832	1814
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2012-DEC-16	2015	1946	2032	2039	1945	1838	1958	1882
2012-DEC-17	1938	2011	1766	1929	1971	1944	1968	1963
2012-DEC-18	1604	1680	1694	1593	1937	1964	1892	1965
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2012-DEC-21	1681	1835	1594	1658	1805	1803	1805	1800
2012-DEC-22	1798	1640	1963	1794	1796	1798	1810	1802
2012-DEC-23	2026	1999	2028	2034	1880	1794	1916	1808
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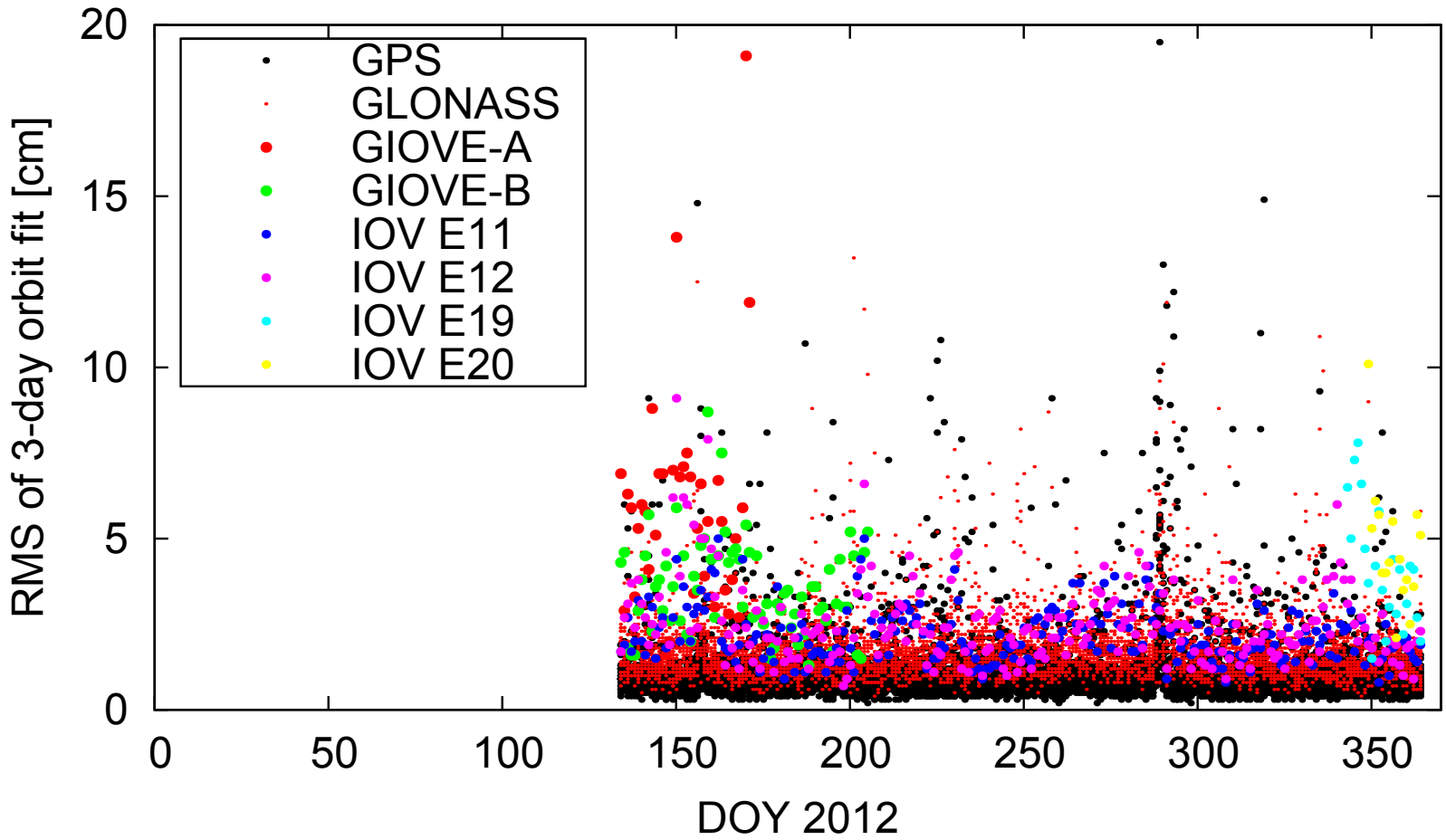
Quality of the MGEX orbit solutions

RMS of an orbit fit through 3 consecutive orbits

MGEX–Solutions from **CODE**:



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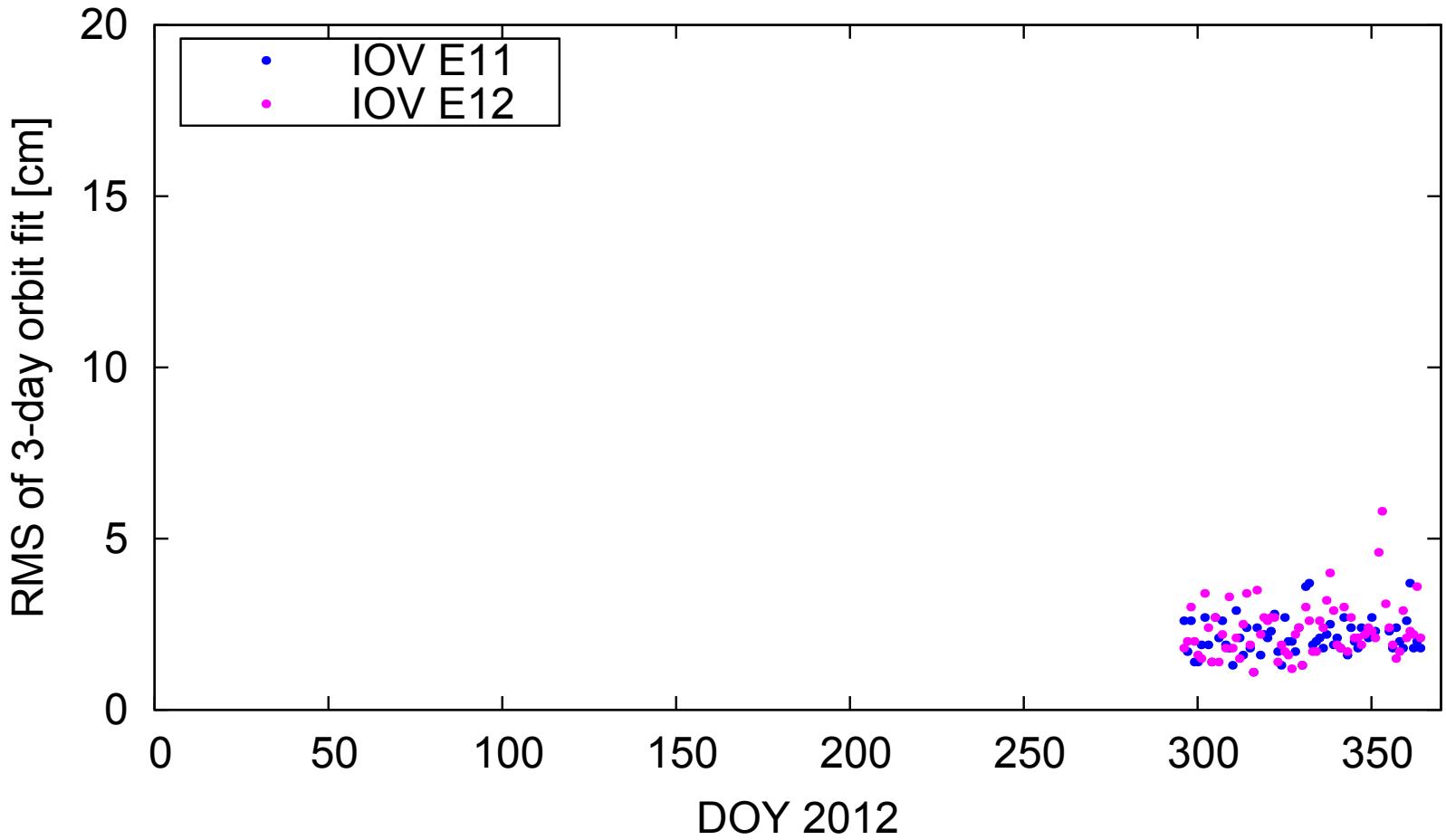
MGEX–Solutions from **TUM**:



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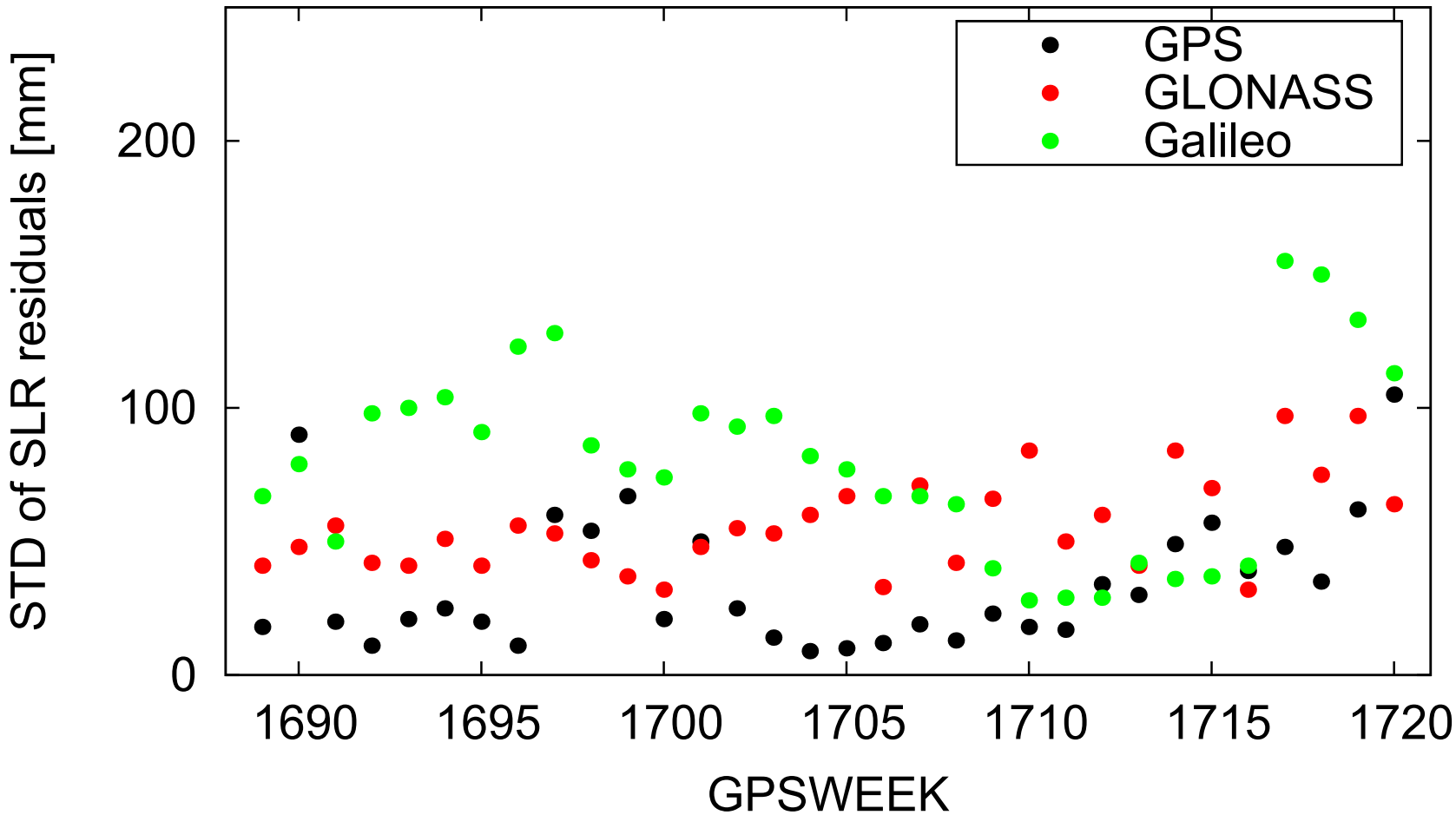

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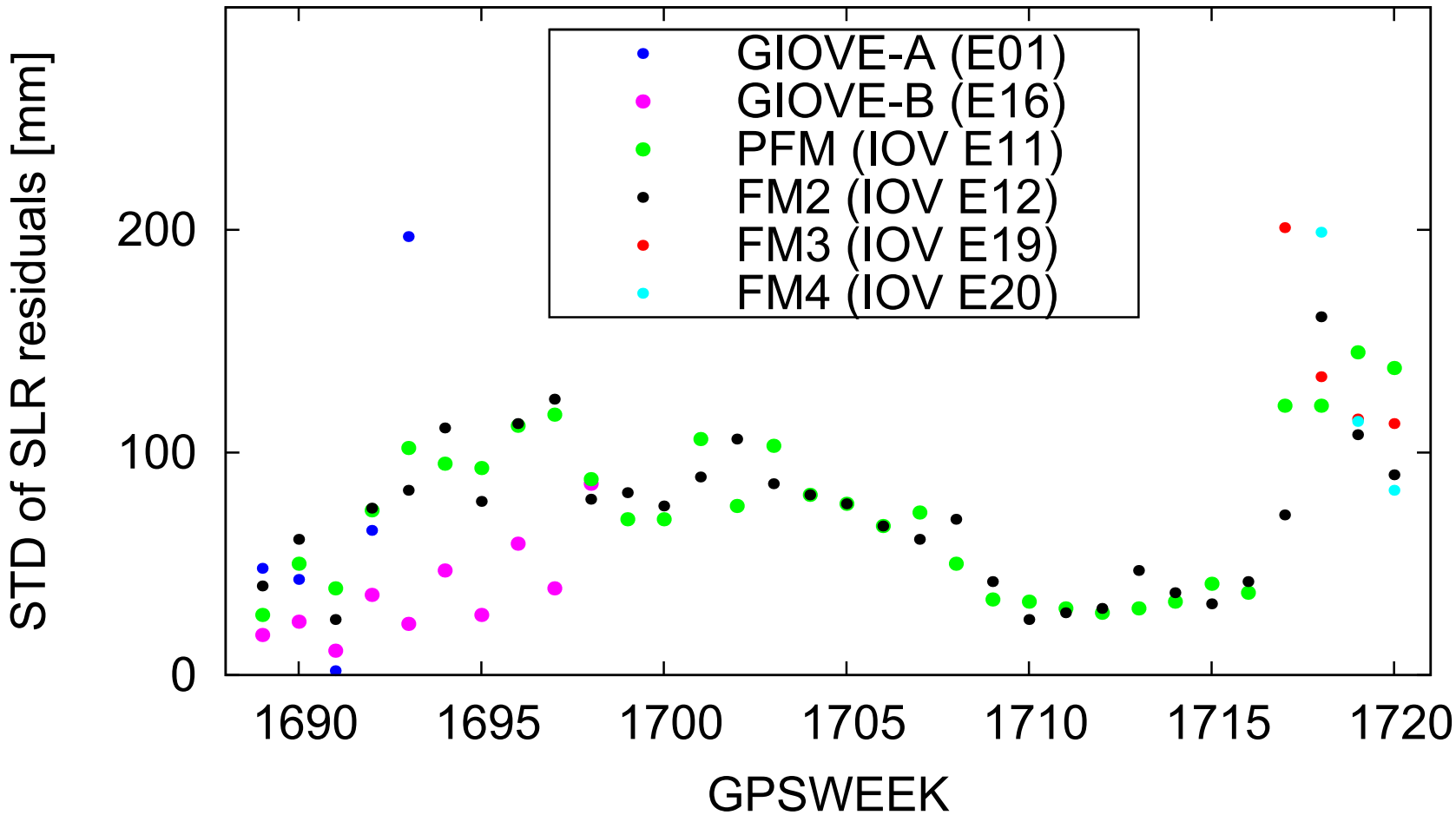

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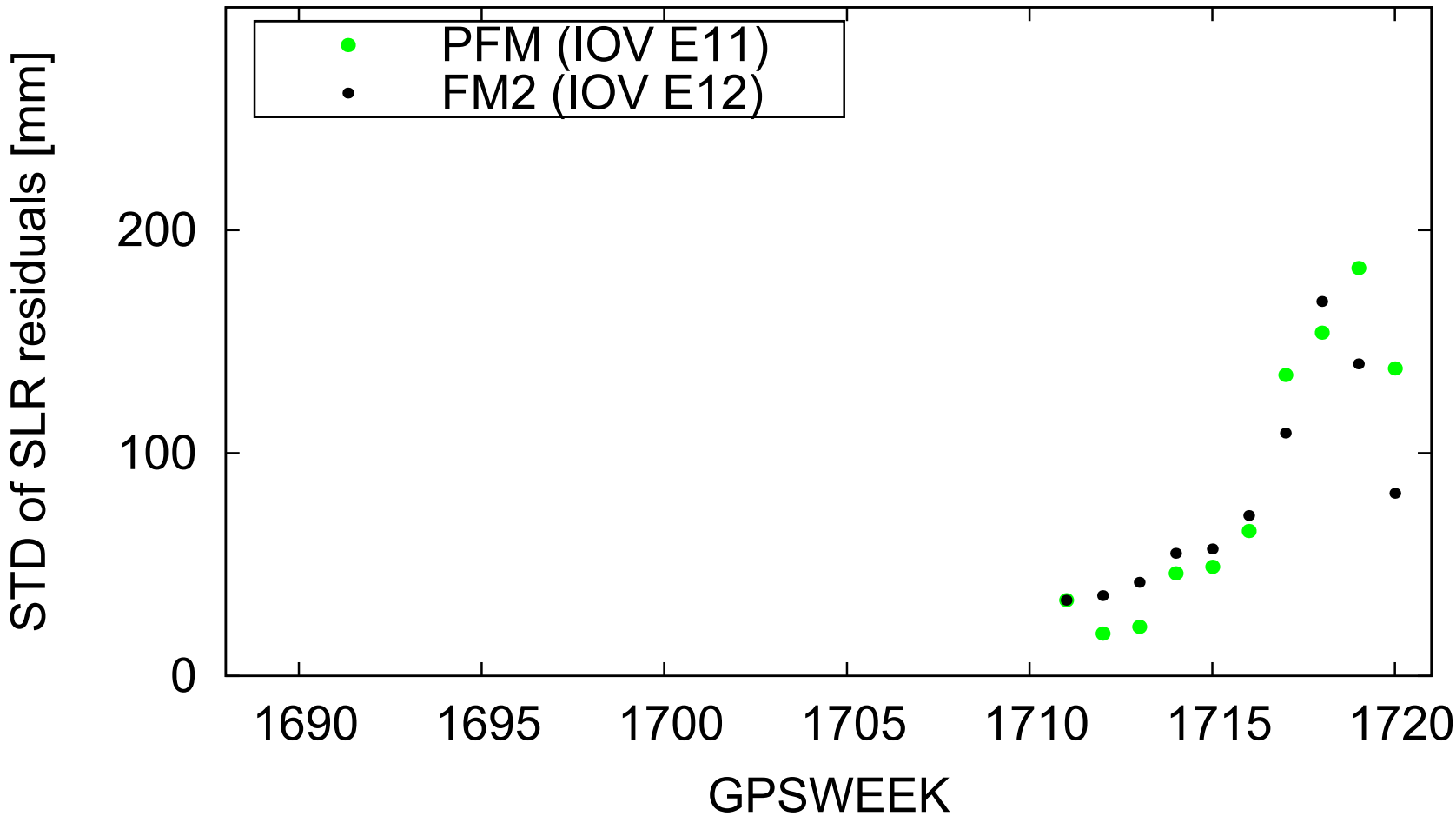

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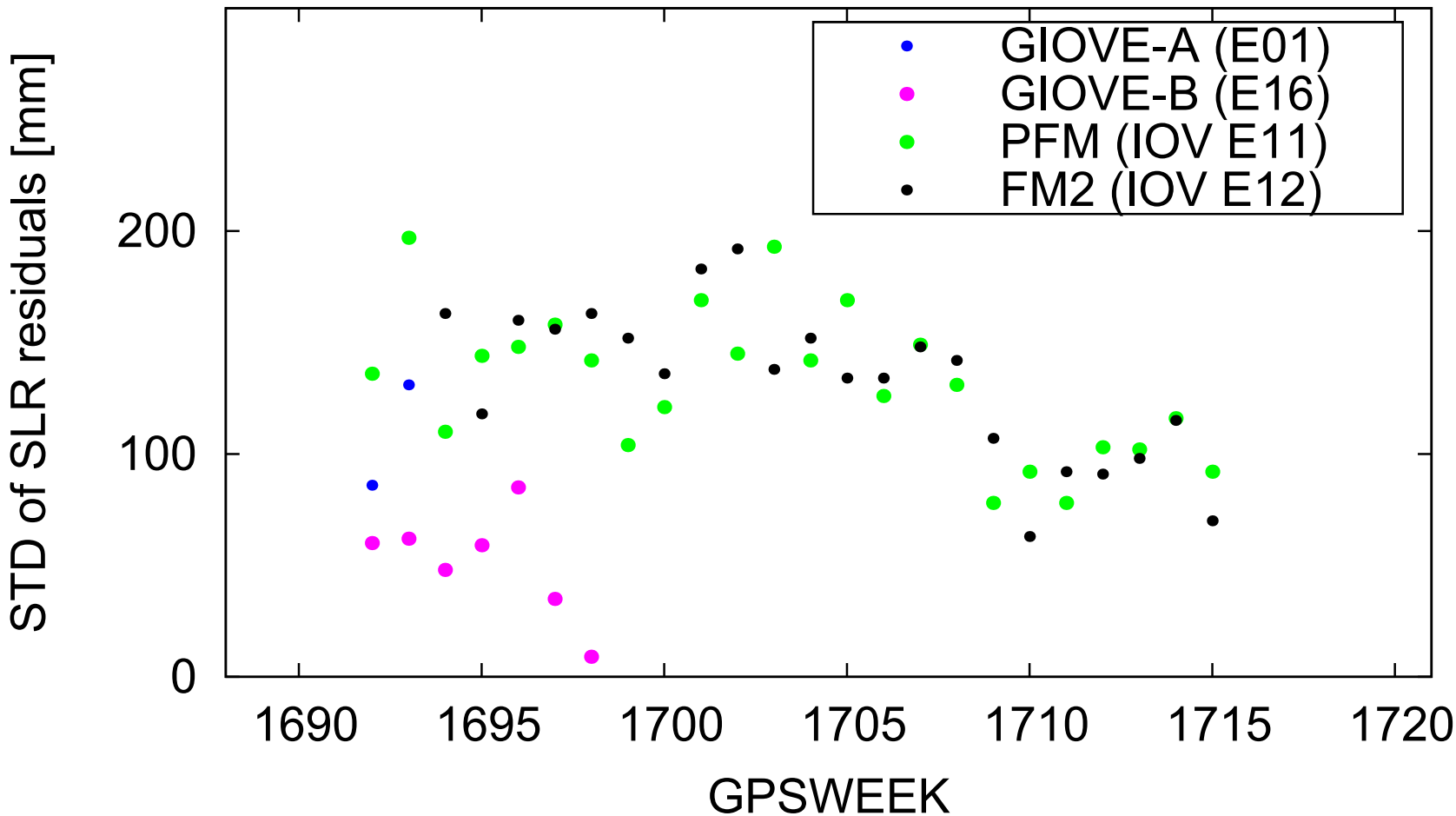
MGEX–Solutions from **CNES/CLS**:



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Product list:	epoch–wise clock corrections per rec. and sat.; inter–system biases per rec.
Distribution:	`ftp://cddis.gsfc.nasa.gov/gnss/products/mgex/`
Timespan covered:	GPS-weeks 1710–1720 (DOY 12/288–12/364)

PPP solution using CODE MGEX–products

Static PPP: GPS-only, GPS+Galileo

Difference to CODE MGEX network solution:

Station	North [mm]		East [mm]		Up [mm]	
	mean	STD	mean	STD	mean	STD
BRUX	1.9	1.2	−4.3	3.2	−1.3	5.3
	1.5	1.4	−5.1	3.1	−1.5	4.8
CUT0	−0.5	1.2	0.3	2.8	−3.6	5.0
	0.0	1.3	0.8	3.1	−4.5	5.1
USN4	−0.4	1.5	0.3	2.5	−1.9	4.2
	−0.4	1.6	2.2	10.5	−3.6	11.2
USN5	−0.4	1.4	0.0	1.8	−2.3	3.8
	−0.2	1.5	−0.8	8.2	−2.9	4.9
WTZZ	0.6	2.1	−0.5	3.1	0.8	6.1
	0.6	2.1	−1.1	3.3	0.6	6.0

(computed from 10 days by the end of 2012)

PPP solution using CODE MGEX–products

Kinematic PPP: GPS-only, GPS+Galileo

Difference to CODE MGEX network solution:

Station	North [mm]		East [mm]		Up [mm]	
	mean	STD	mean	STD	mean	STD
BRUX	1.5	7.7	−4.4	7.8	−0.8	18.5
	1.1	8.2	−4.5	9.0	−0.5	29.5
CUT0	0.8	12.8	−1.6	23.9	−3.7	29.6
	0.9	16.8	−1.6	26.3	−4.6	30.7
USN4	−1.2	6.7	−1.3	8.2	2.1	19.1
	−1.0	6.7	−0.7	8.3	1.5	19.7
USN5	−1.0	7.3	−0.6	8.4	2.3	20.2
	−1.1	10.6	−0.4	10.4	2.2	22.2
WTZZ	0.2	9.9	−0.5	9.1	0.0	22.8
	0.1	9.6	−0.7	8.8	0.3	22.1

(computed from 10 days by the end of 2012)

PPP solution using CODE MGEX–products

Static PPP for BRUX: Galileo–only

Difference to CODE MGEX network solution:

Date	Number of observations	North [mm]	East [mm]	Up [mm]	3D [mm]
2012-Dec-20	440	−1.8	8.3	14.0	16.4
2012-Dec-21	585	−2.9	−12.0	−42.0	43.8
2012-Dec-22	516	−76.6	14.2	−19.8	80.4
2012-Dec-23	446	55.8	−6.8	335.0	340.7
2012-Dec-24	546	2.0	−31.4	−54.1	62.6
2012-Dec-25	610	−4.4	−3.1	8.7	10.2
2012-Dec-26	448	6.4	−6.0	−84.3	84.8
2012-Dec-27	471	20.1	−23.4	−16.6	35.0
2012-Dec-28	674	−27.8	0.6	−11.7	30.2
2012-Dec-29	438	91.5	−54.7	6.2	106.8

PPP solution using CODE MGEX–products

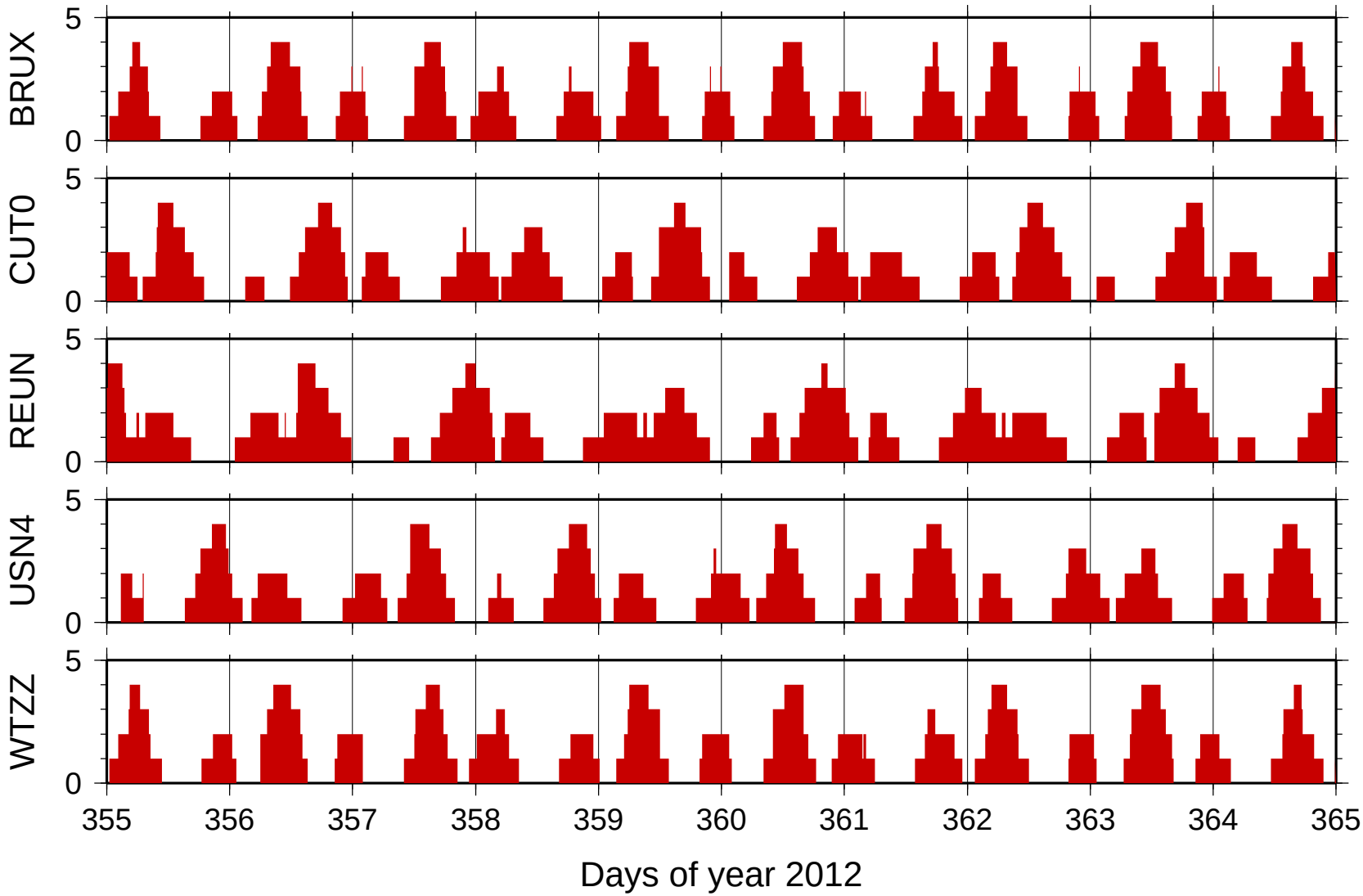
Static PPP for USN4: Galileo–only

Difference to CODE MGEX network solution:

Date	Number of observations	North [mm]	East [mm]	Up [mm]	3D [mm]
2012-Dec-20	460	85.7	−80.8	72.9	138.5
2012-Dec-21	232	3266.7	−870.4	7438.2	8170.4
2012-Dec-22	730	7.0	−60.3	−92.9	111.0
2012-Dec-23	556	−24.3	−12.0	37.5	46.3
2012-Dec-24	280	−198.1	595.0	−372.5	729.4
2012-Dec-25	610	24.9	−89.6	−64.1	112.9
2012-Dec-26	682	67.1	11.1	−5.1	68.2
2012-Dec-27	412	−199.6	89.1	−37.0	221.7
2012-Dec-28	396	43.5	−27.4	129.6	139.4
2012-Dec-29	772	−10.8	−21.6	−37.4	44.5

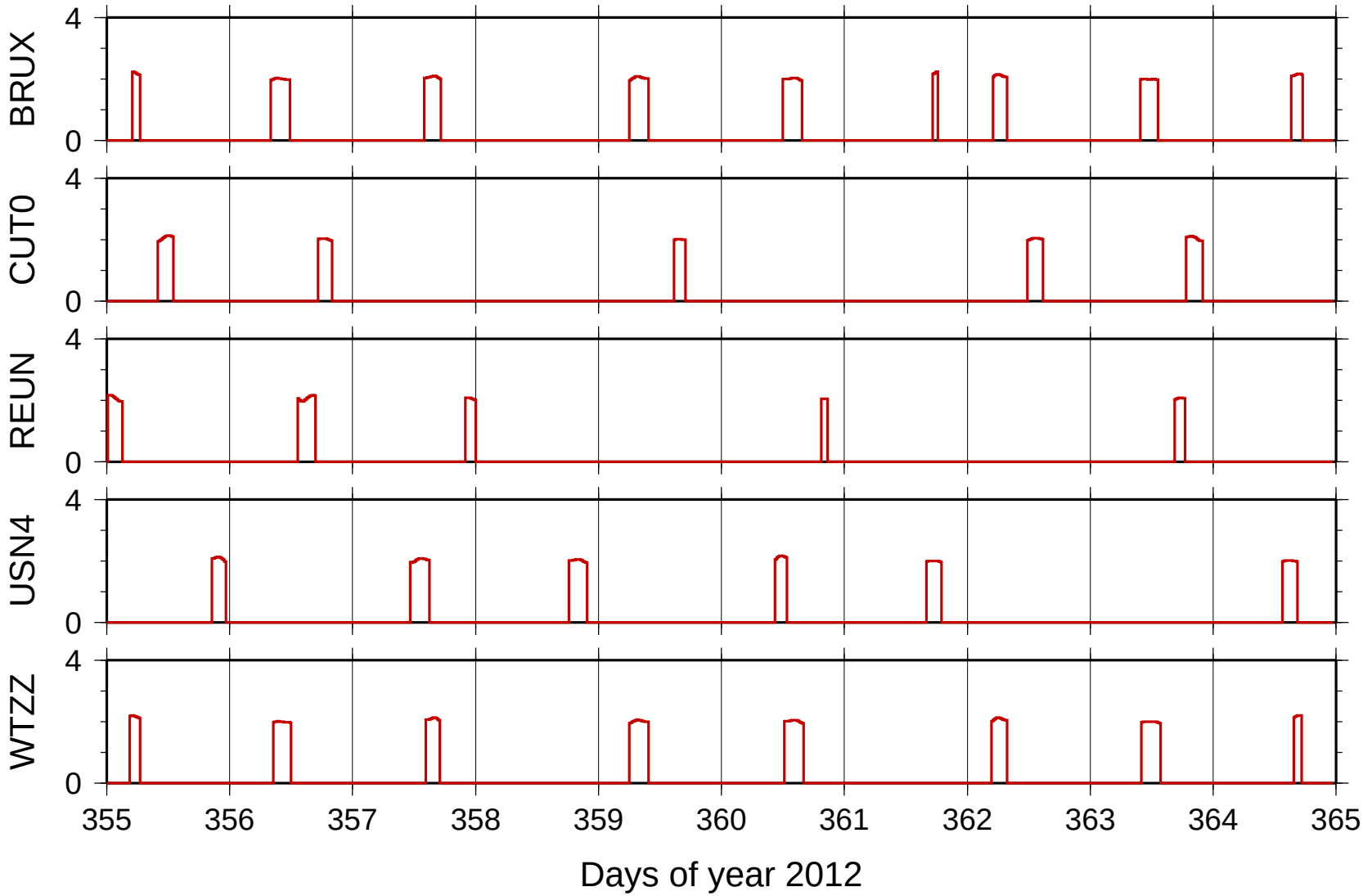
PPP solution using CODE MGEX–products

Number of Galileo–satellites in view



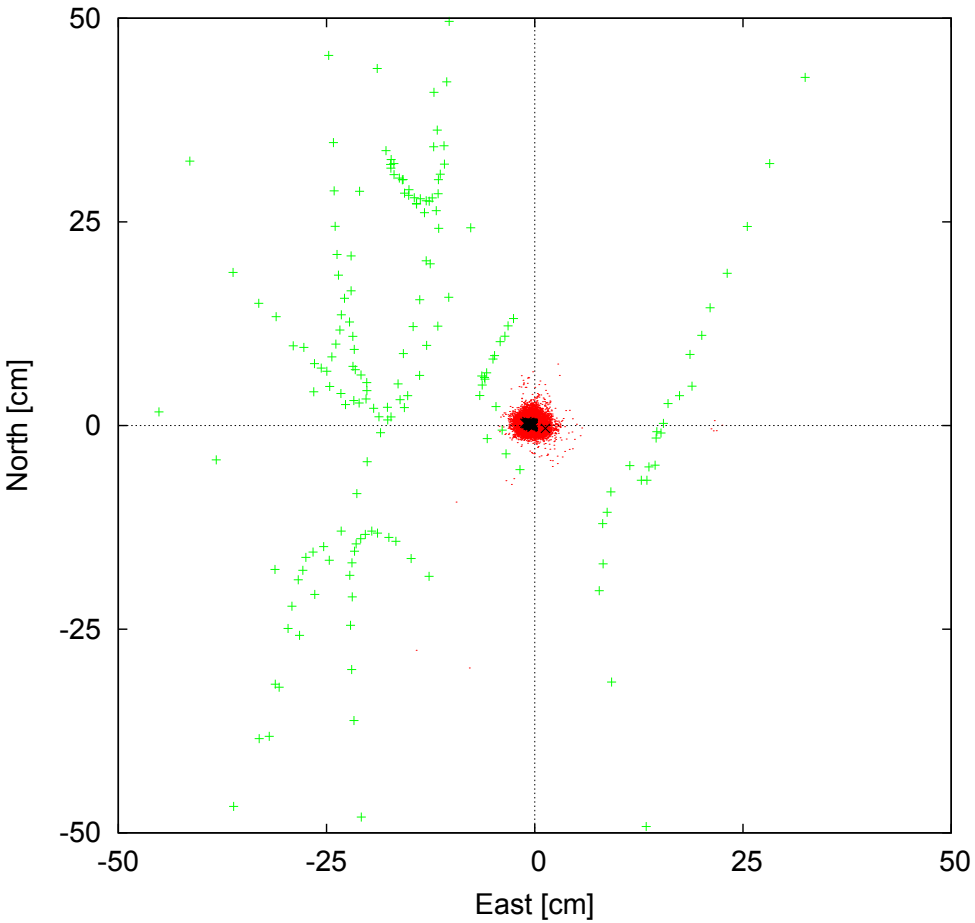
PPP solution using CODE MGEX–products

PDOP for Galileo–satellites (only, if >4 satellites in view)



PPP solution using CODE MGEX–products

Differences between static and kinematic coordinates
for station BRUX



× Static GPS–only
● Kinematic GPS–only
+ Kinematic Galileo–only

Why going from GPS–only to multi–GNSS?

More systems: more problems

- Receiver and antenna technique becomes more complex. (e.g., calibration of the antenna phase center variations)

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  (labelled with the correct data type)
- More satellite types need to be modelled.

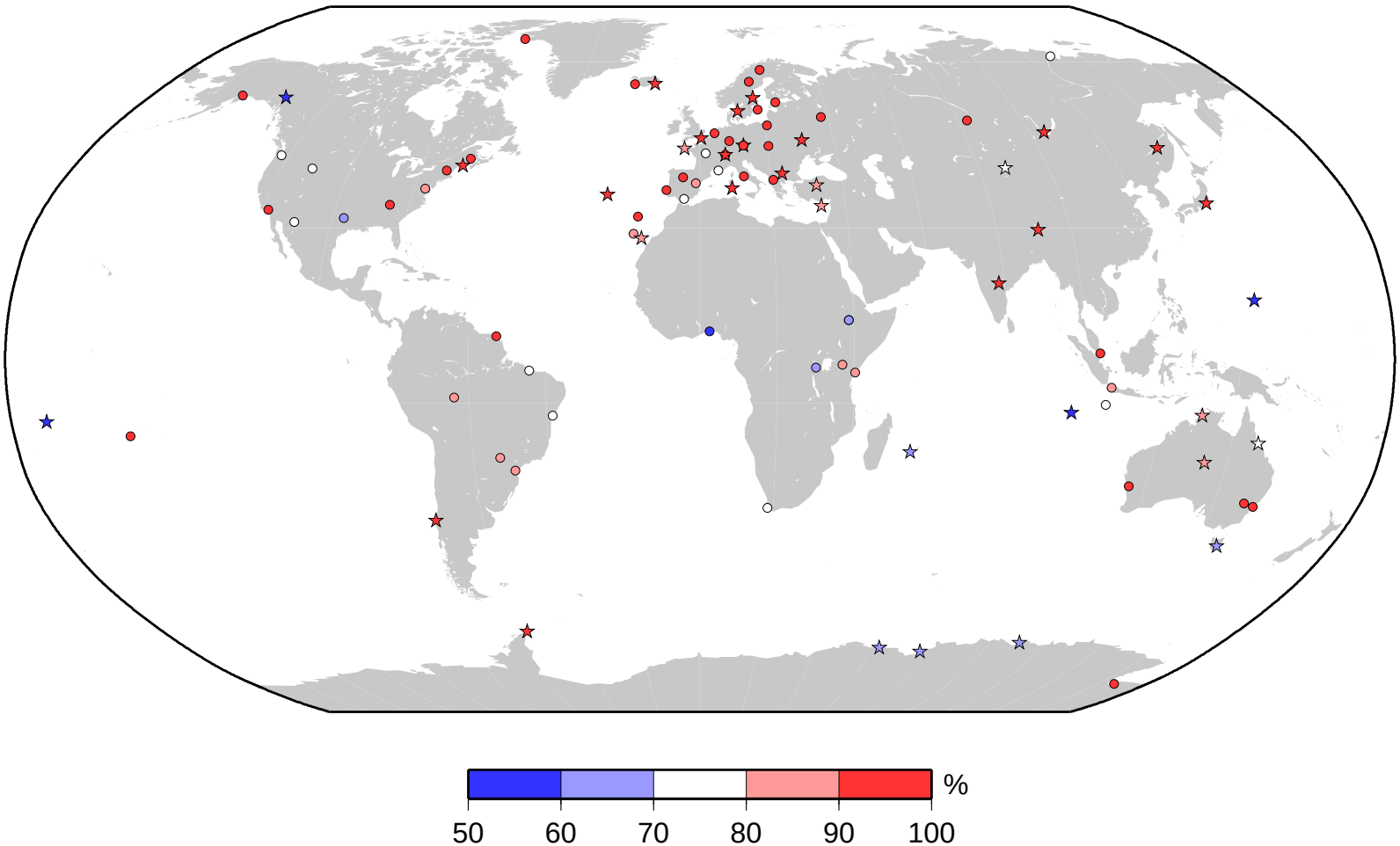
GPS Block IIF

GLONASS–M

Galileo IOV

More systems: reducing GNSS–specific effects

92 globally distributed GPS/GLONASS stations, 2008–2010



PhD thesis from M. Meindl: *Geodätisch-geophysikalische Arbeiten in der Schweiz*, vol. 83.

More systems: reducing GNSS–specific effects

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GPS	single system: GPS
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CMB	GPS/GLONASS; common receiver clock for both systems, but one ISB per day

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Solution	N	E	U	Total
CMB	2.1 mm	2.1 mm	5.6 mm	3.6 mm
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GLO	4.6 mm	5.7 mm	9.7 mm	7.3 mm

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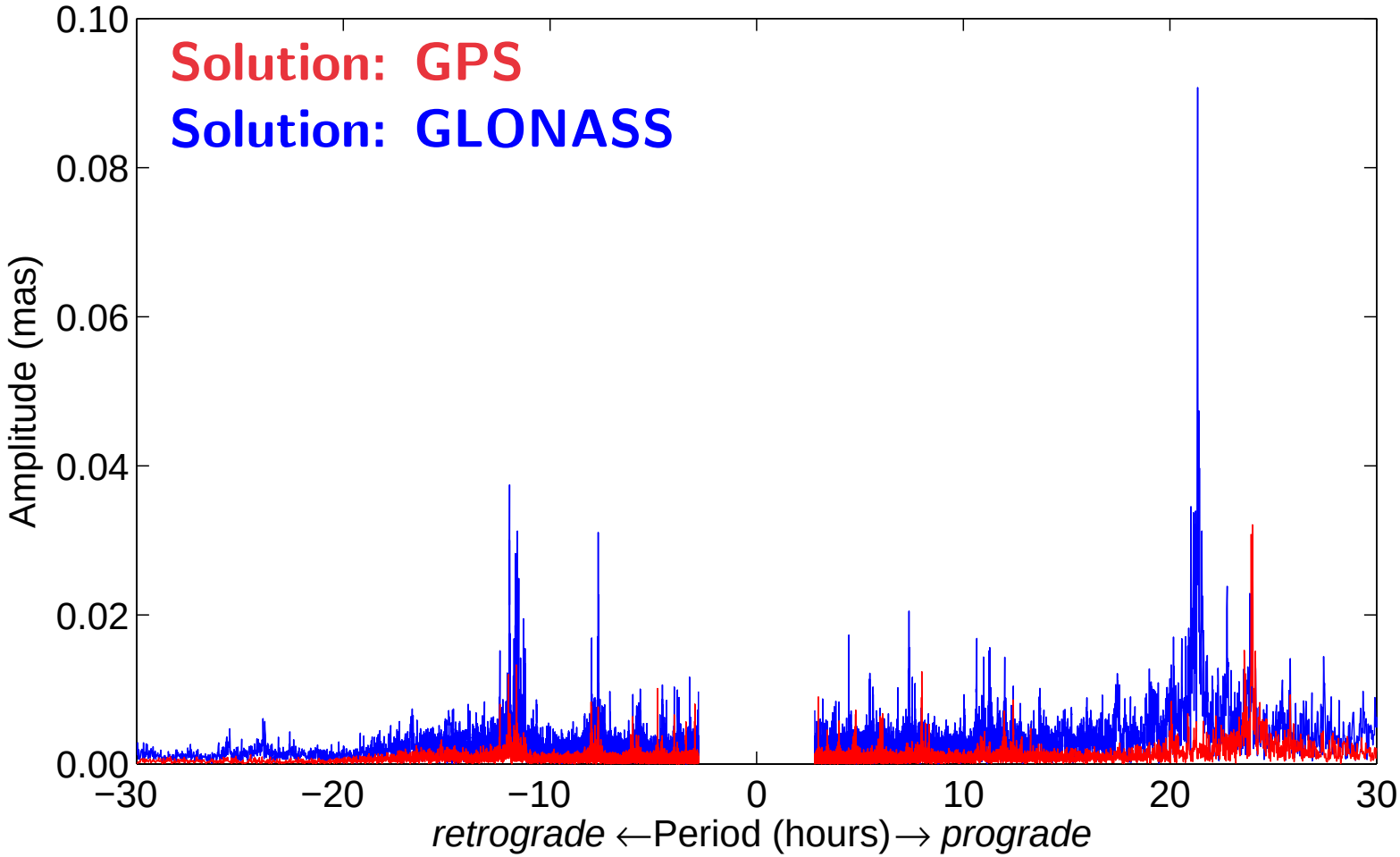
More systems: reducing GNSS–specific effects

Spectra of the daily ERP series, 2008–2010



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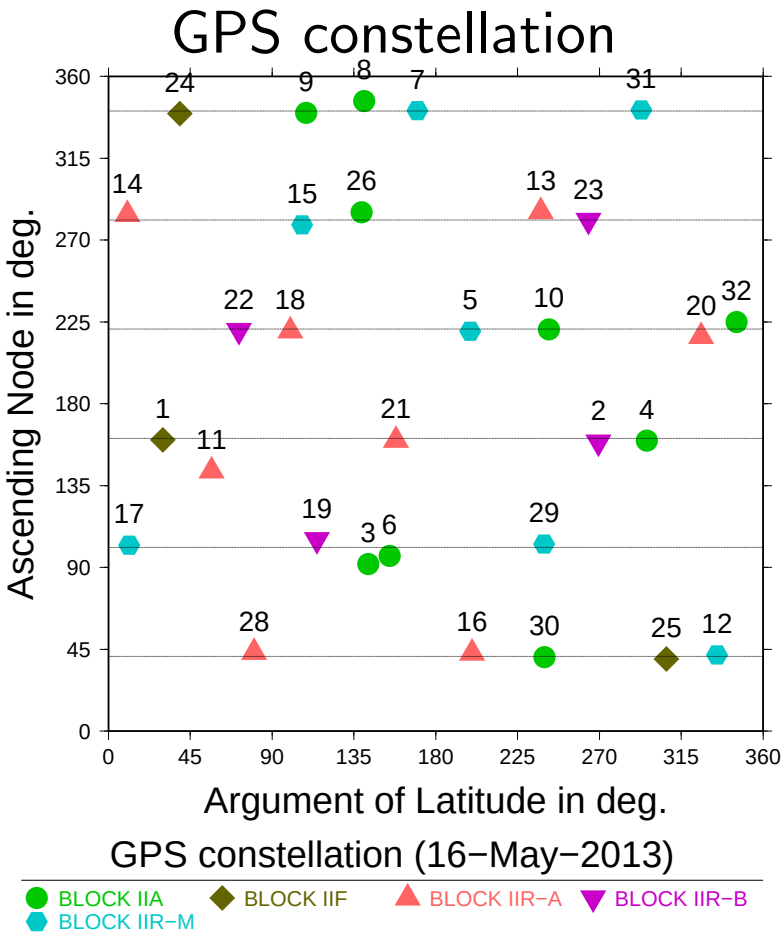
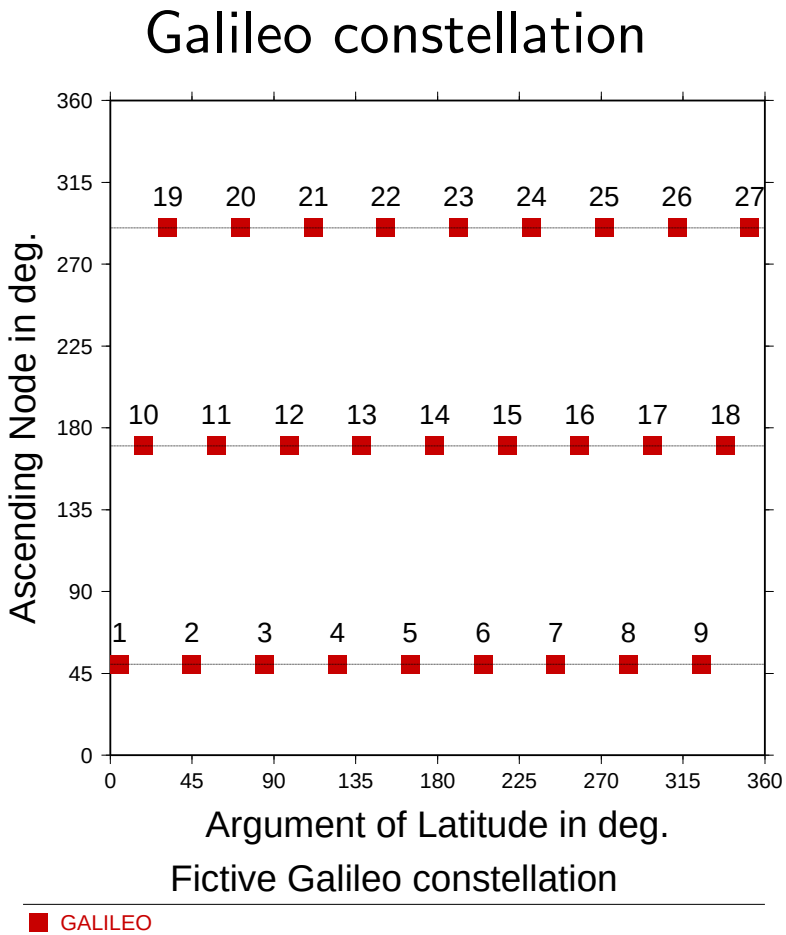
Looking at the satellite geometry

Status of the GNSS–constellations

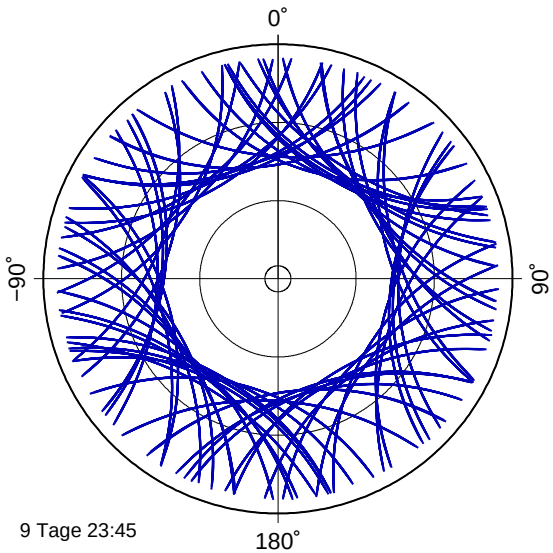
Day of year 2013:136 (16. May 2013)



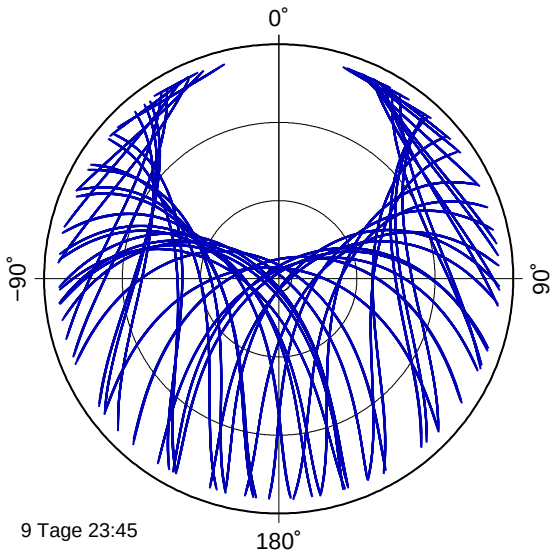


Looking at the satellite geometry

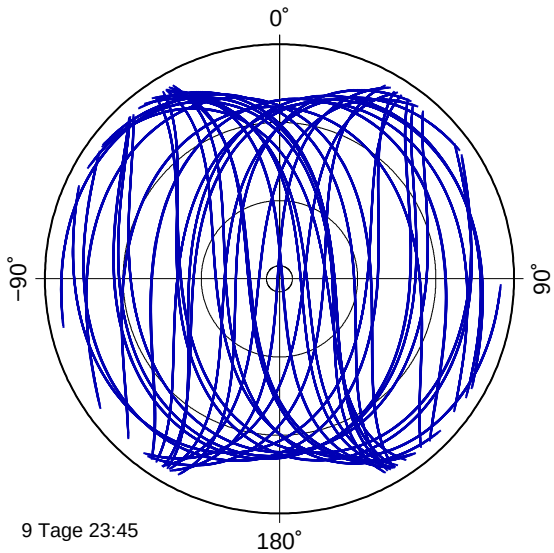
Station at the pole



Mid-latitude station



Station at the equator



- GPS: all satellites fly only on its own sky track.

Looking at the satellite geometry

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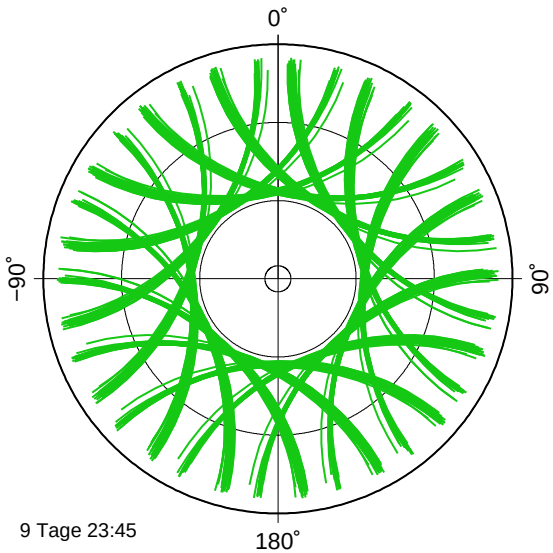

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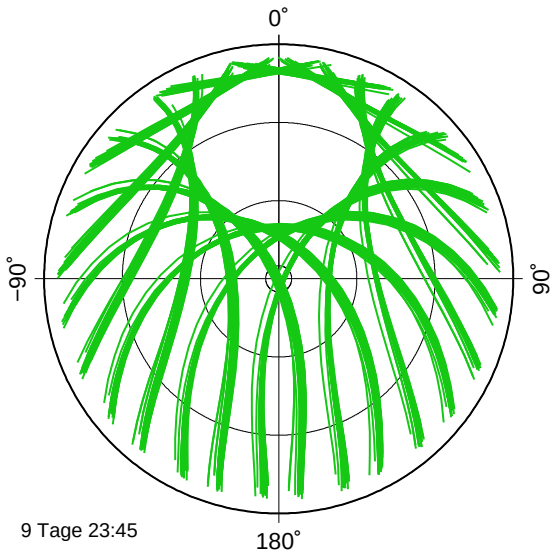

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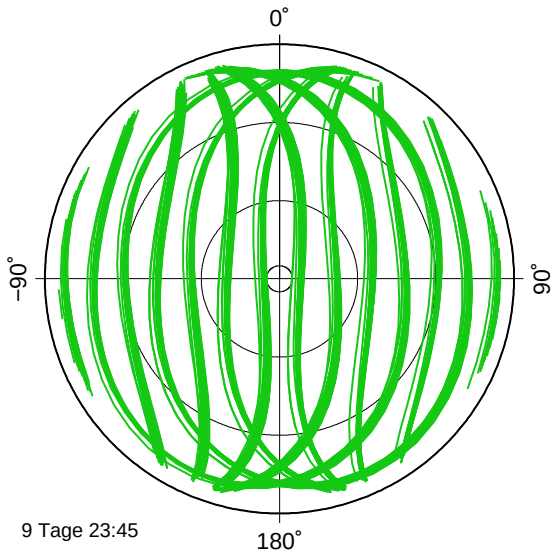

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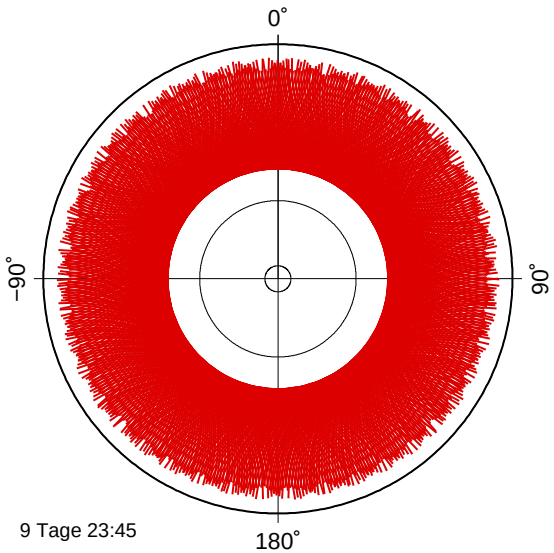

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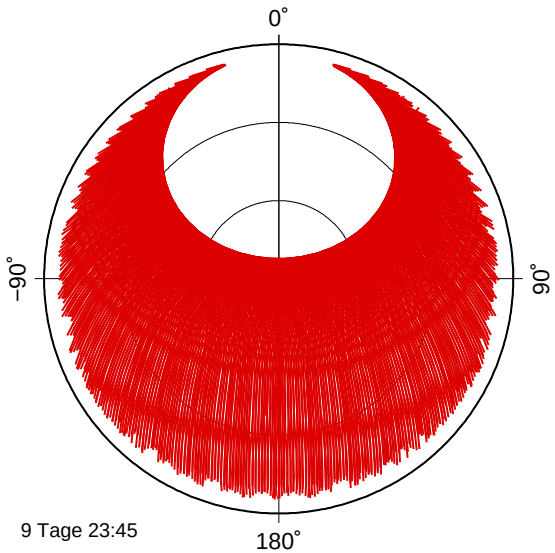

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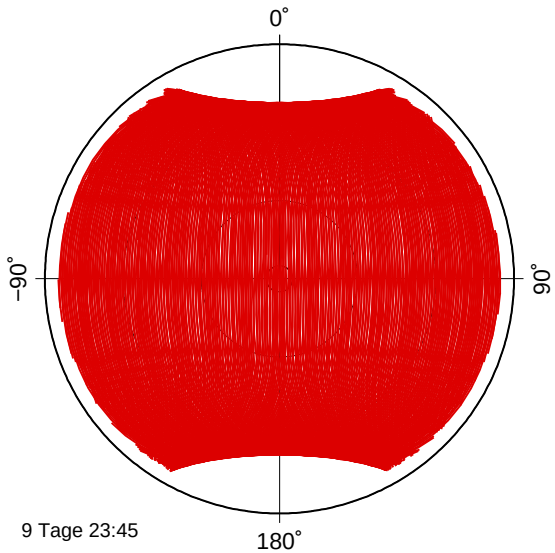

- GPS: all satellites fly only on its own sky track.
- GLONASS: all satellites fly on one and the same sky track.
- Galileo: the satellite tracks cover the full sky.

PDOP: Position Dilution of Precision

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- 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:

$$\mathbf{C_{YY}} = \begin{bmatrix} q_{XX} & q_{XY} & q_{XZ} \\ q_{YX} & q_{YY} & q_{YZ} \\ q_{ZX} & q_{ZY} & q_{ZZ} \end{bmatrix}$$

$$PDOP = \sqrt{q_{XX} + q_{YY} + q_{ZZ}}$$

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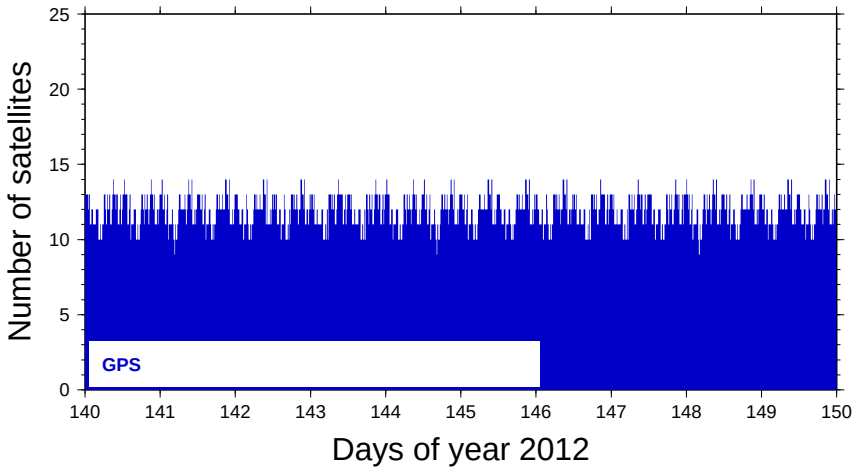
- **The smaller the PDOP value is the better a position can be derived.**

PDOP: satellite geometry for ground stations

Station at the pole



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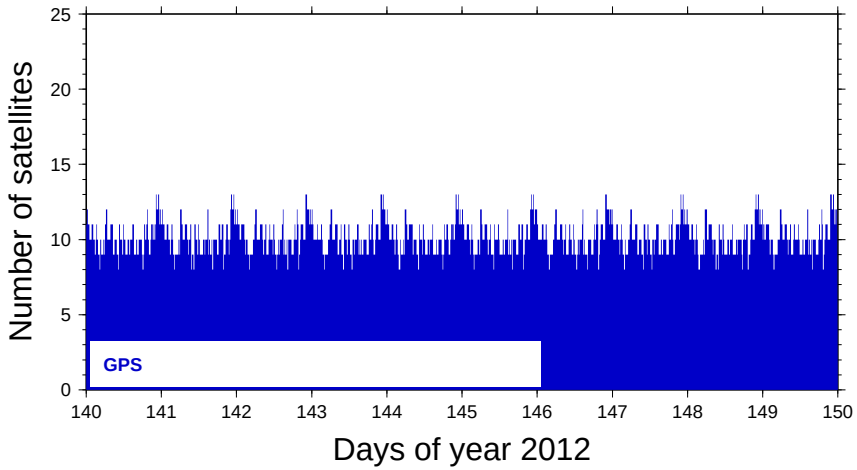

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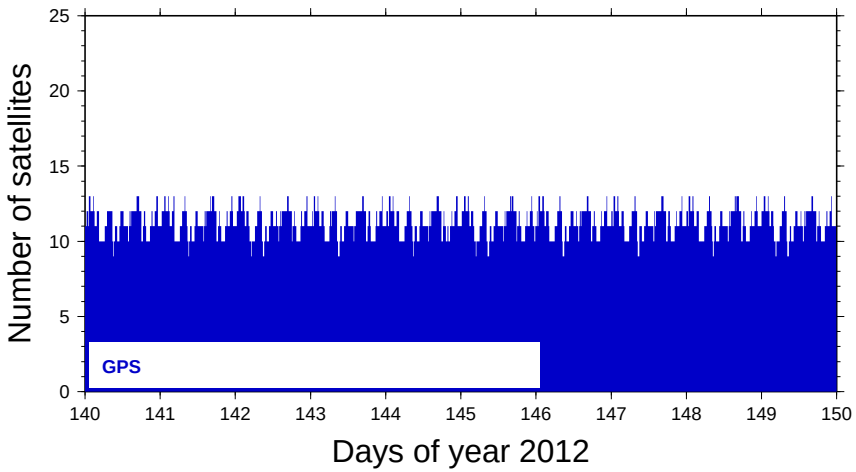

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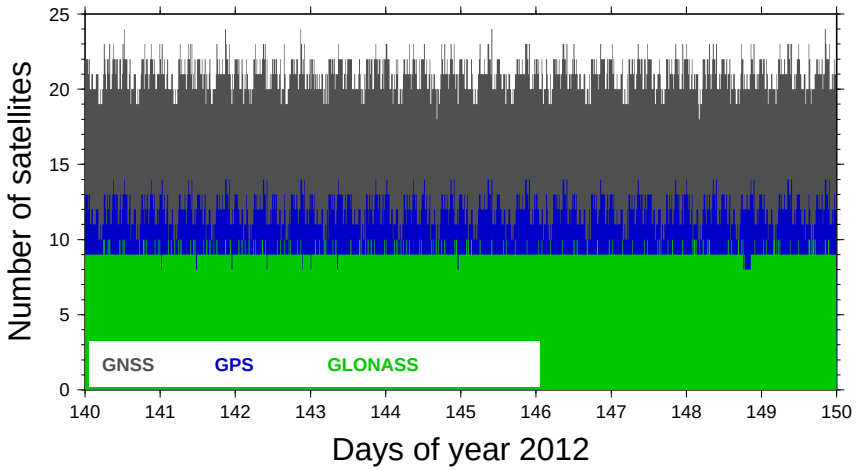
PDOP: satellite geometry for ground stations

Station at the pole



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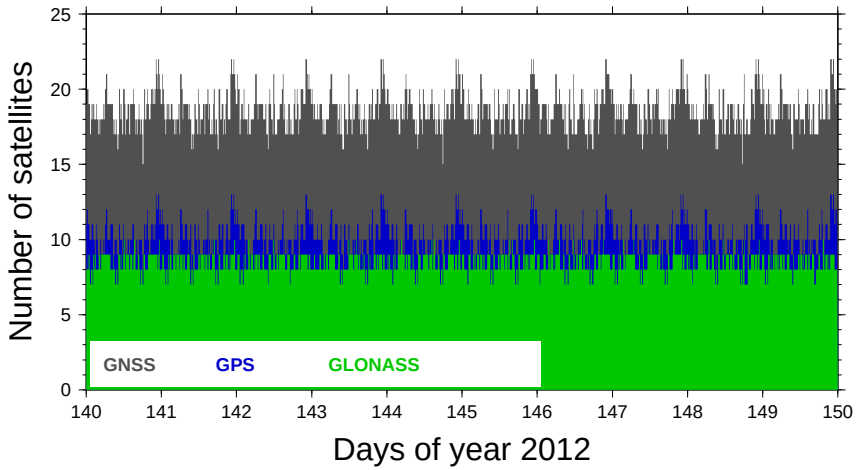

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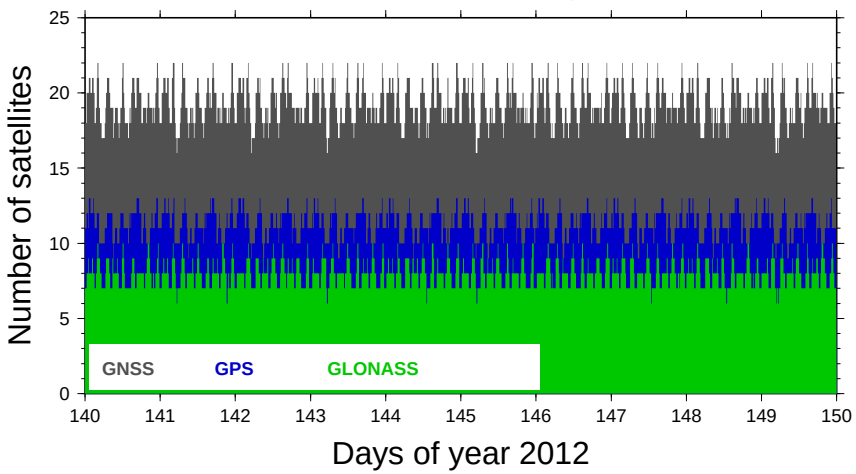
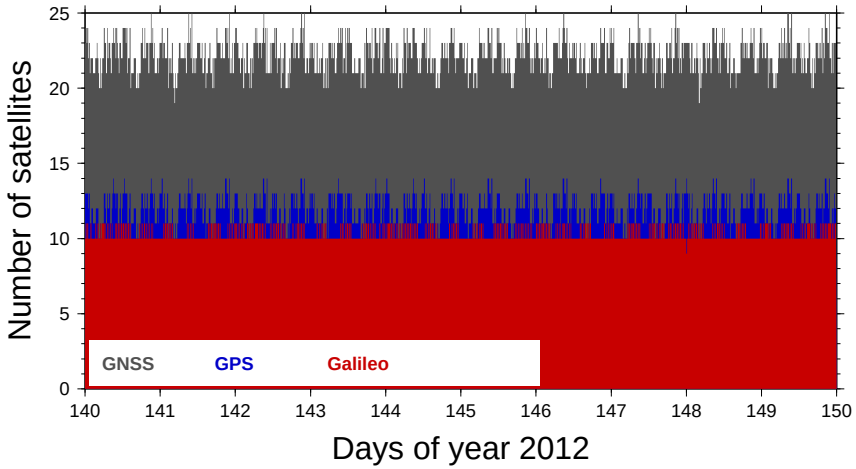


- GPS: the variation of the number of observed satellites shows a clear daily pattern in all latitudes.
- GLONASS: small variations in the number of observed satellites can be found at the pole and mid–latidutes but the three orbital planes dominate at the equator.

PDOP: satellite geometry for ground stations

Station at the pole



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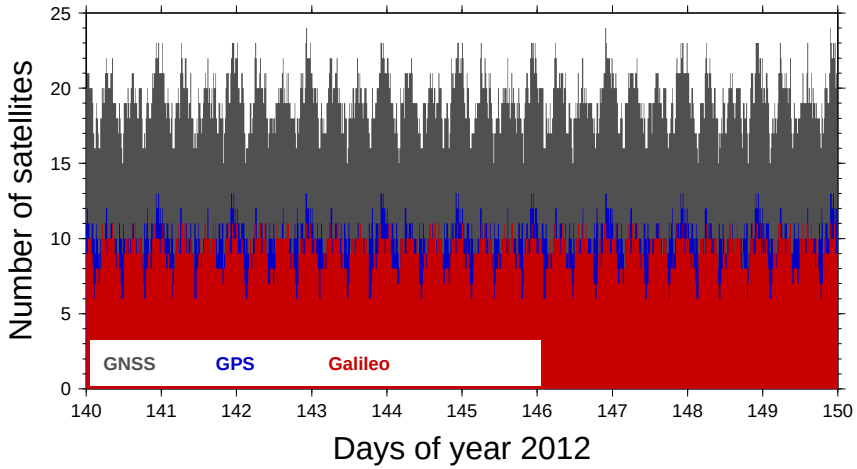

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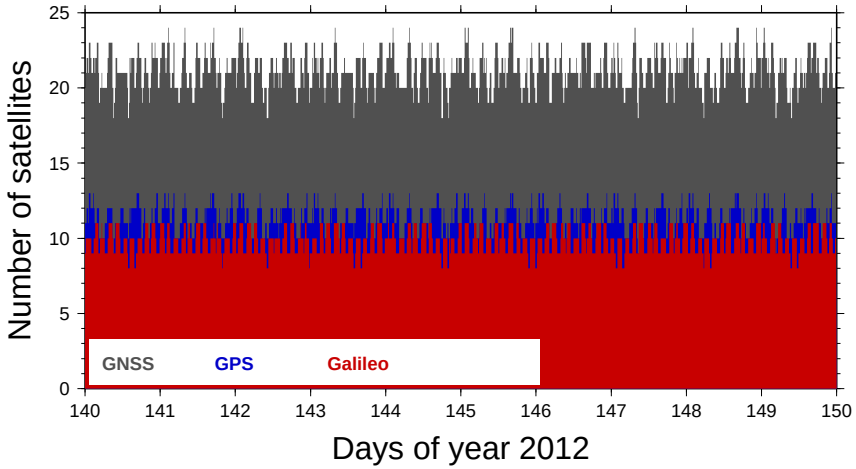

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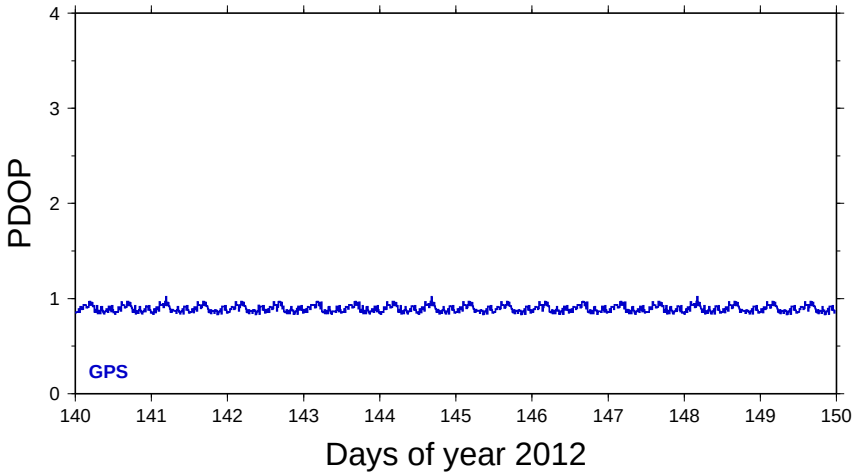

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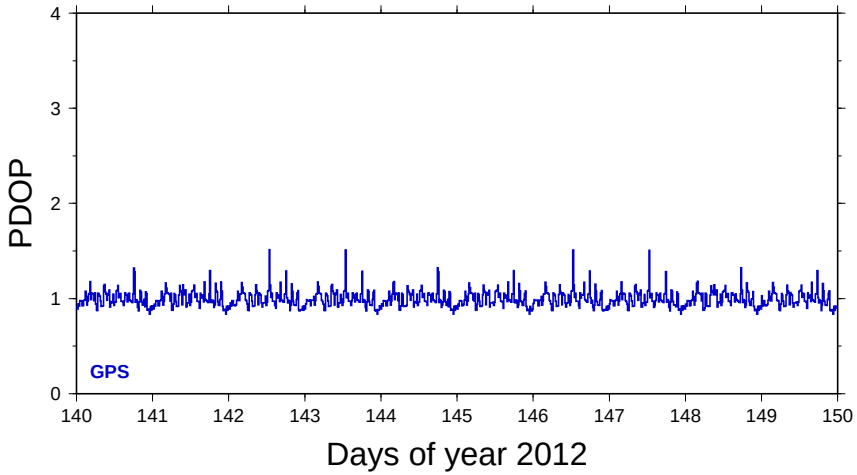

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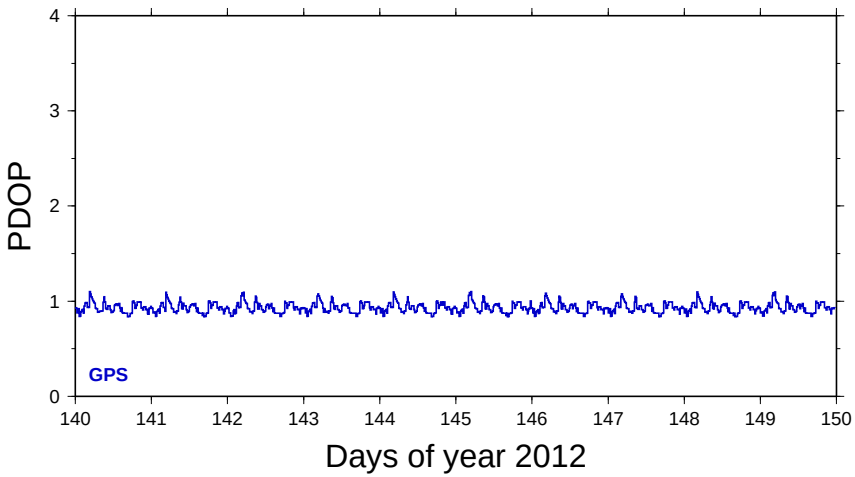

PDOP: satellite geometry for ground stations

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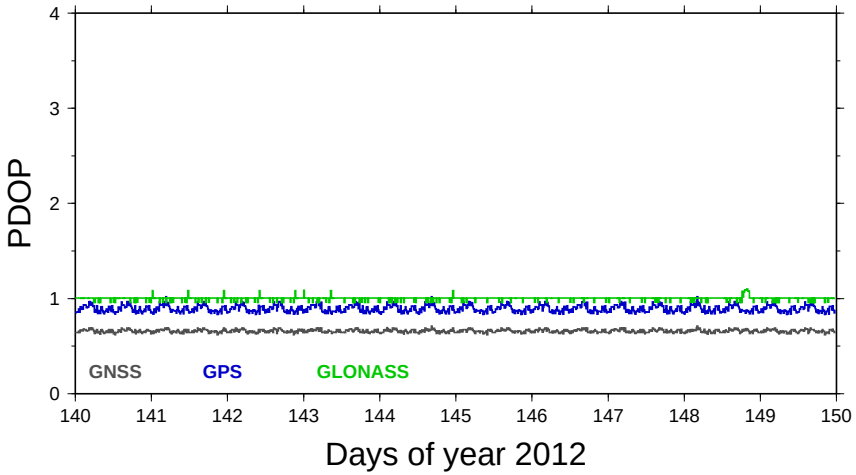

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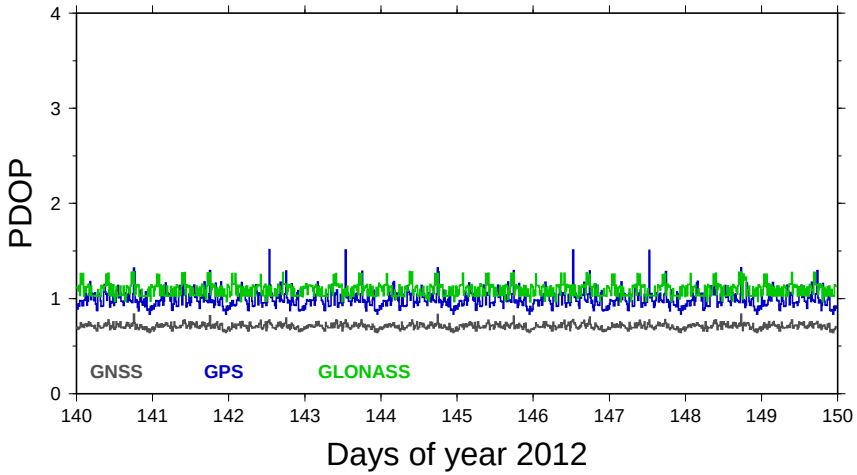

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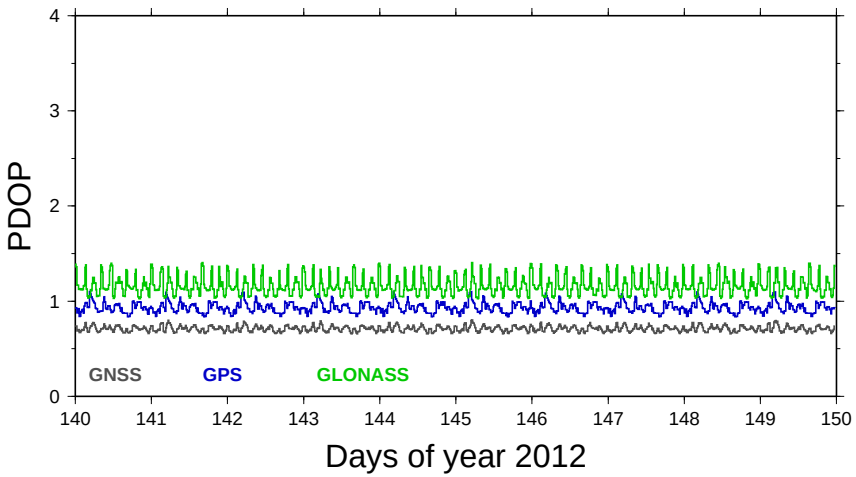

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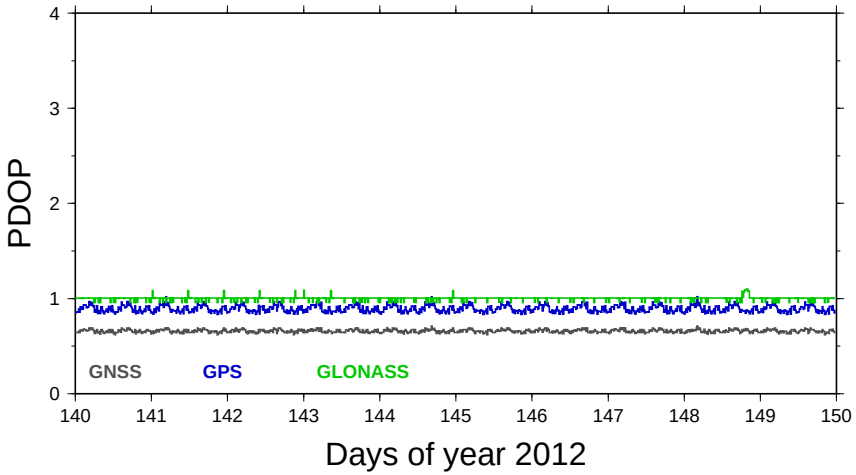

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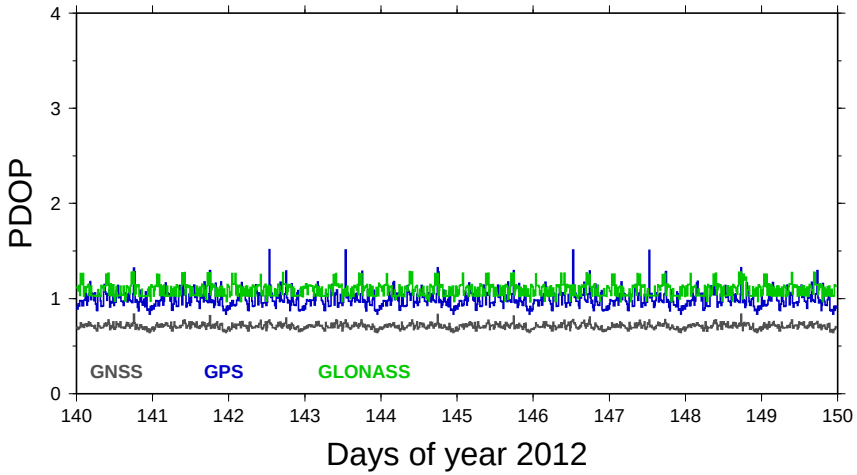

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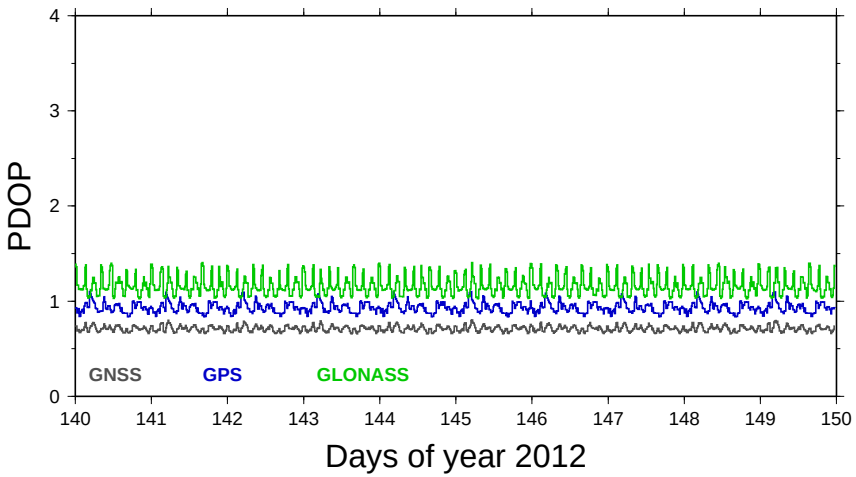

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PDOP: satellite geometry for ground stations

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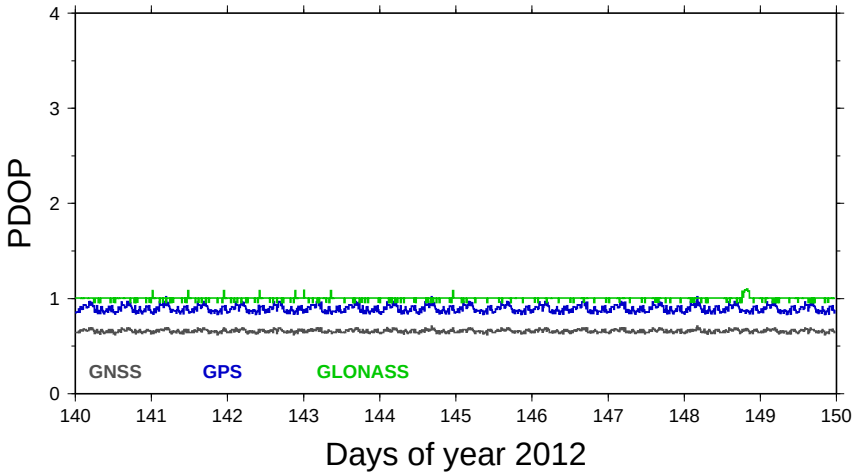

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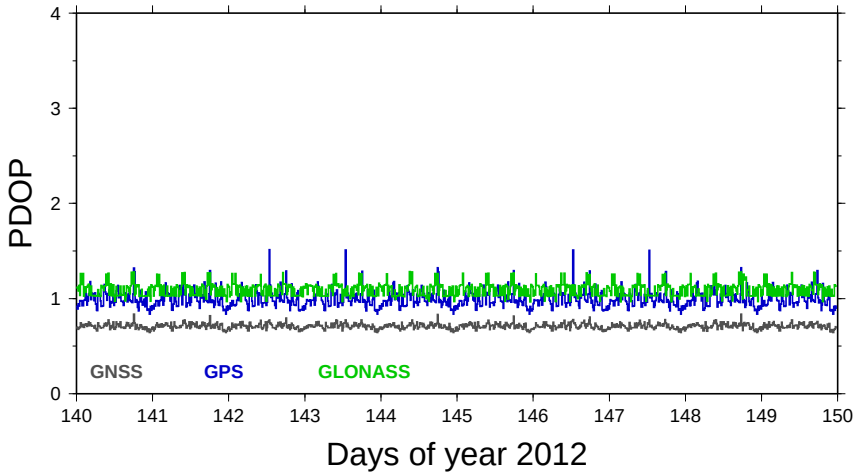

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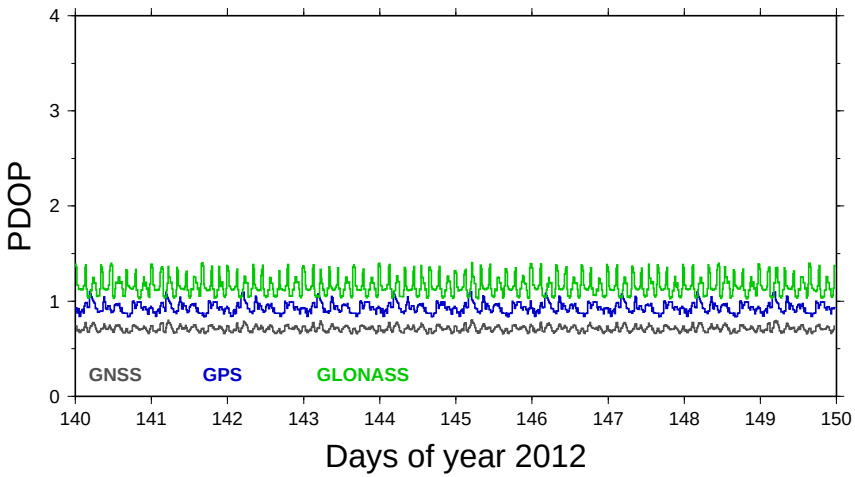

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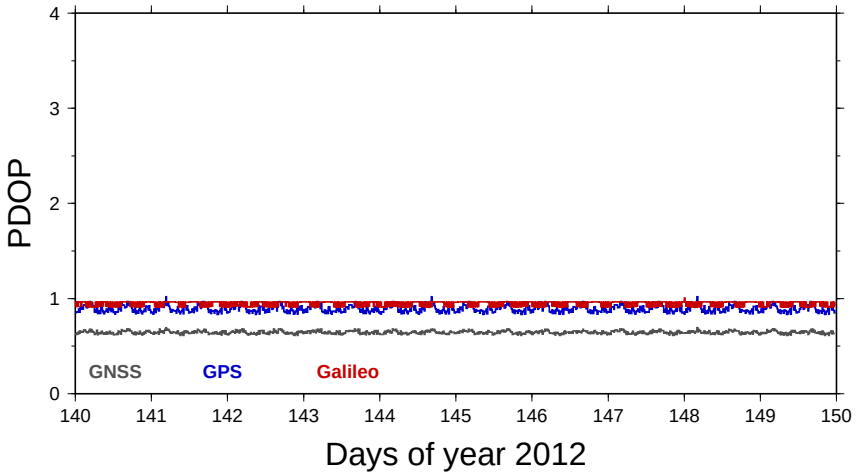
- The combination of the measurements from both systems helps to reduce the system–specific variations and improve the satellite geometry in general.

PDOP: satellite geometry for ground stations

Station at the pole



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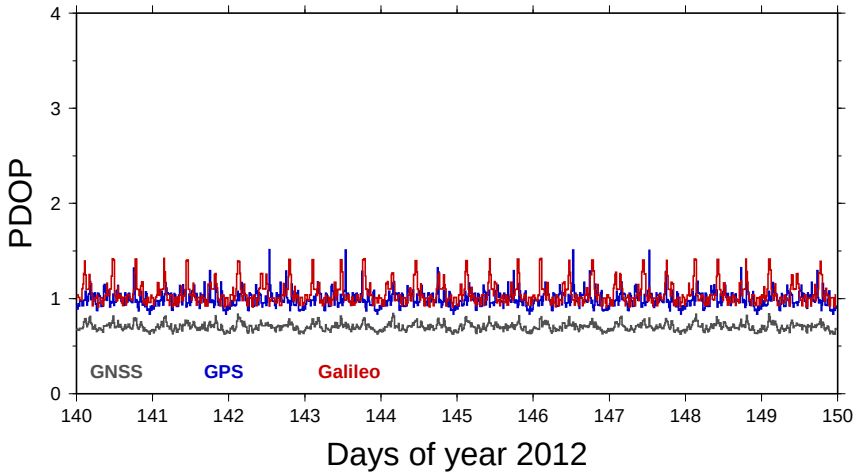

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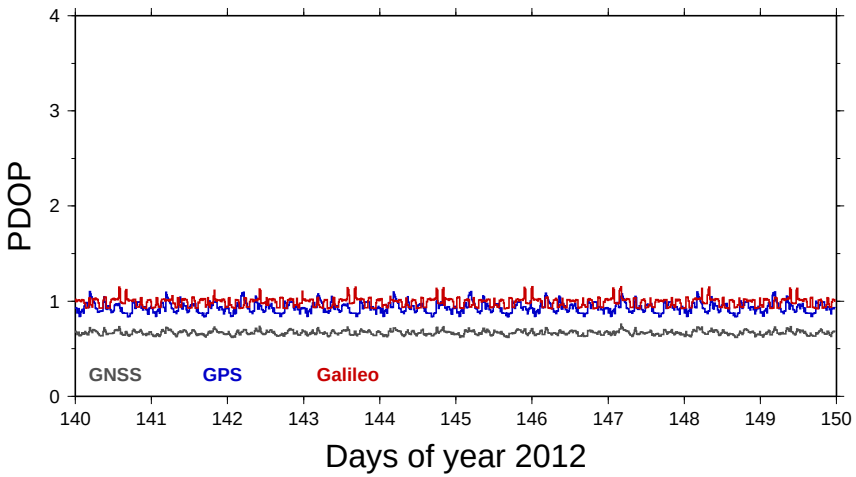

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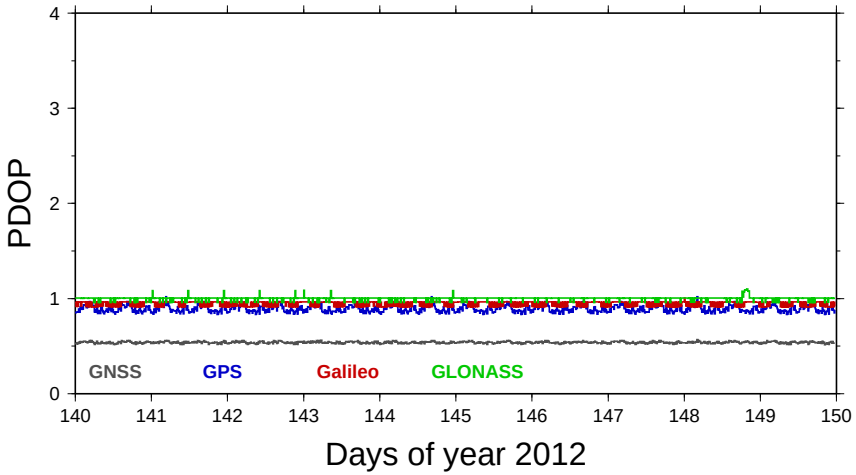
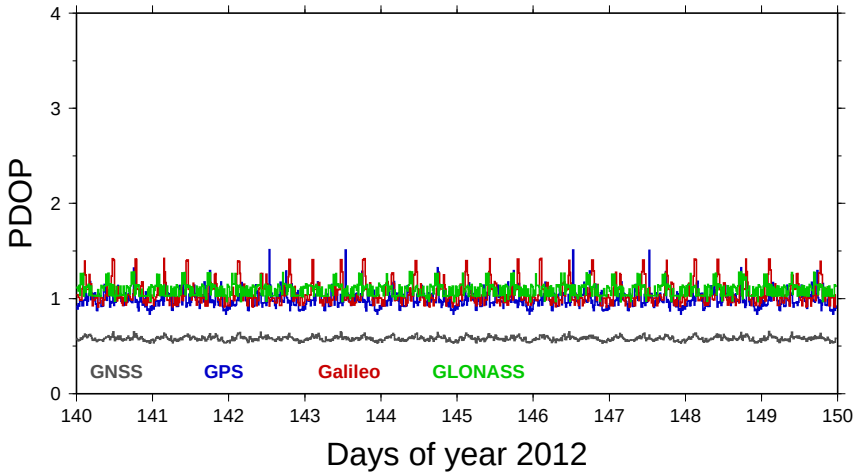
PDOP: satellite geometry for ground stations

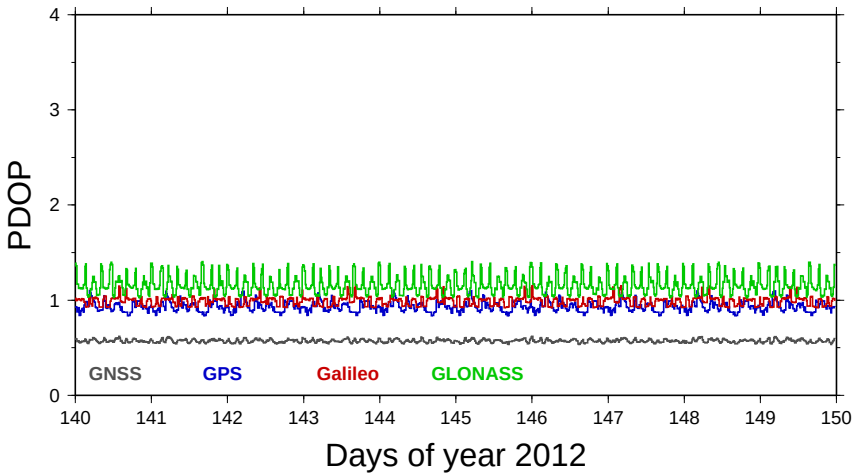
Station at the pole



Mid-latitude station



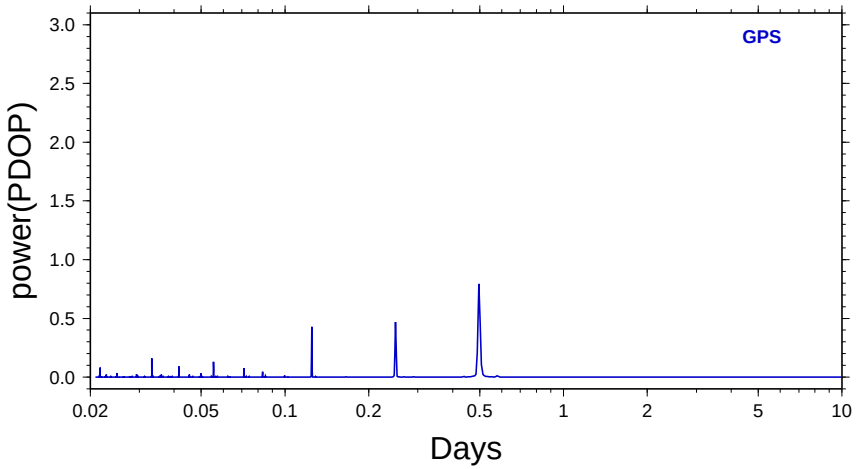
Station at the equator



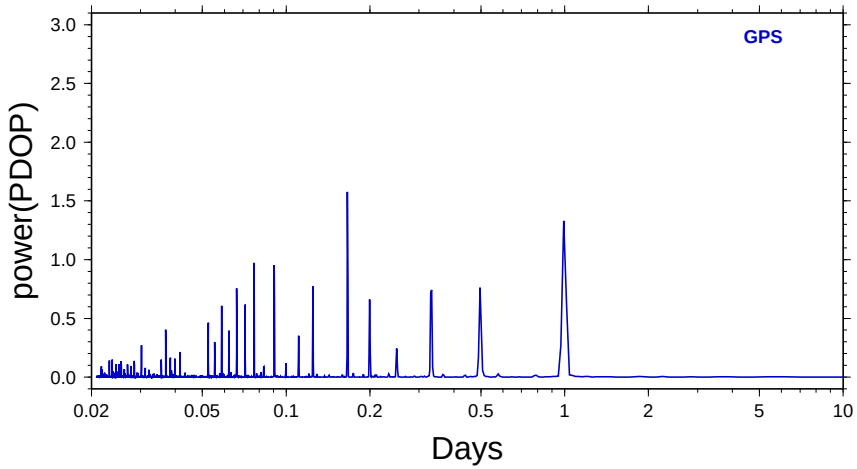
- The variation of the PDOP in time is analogue to the variation of the number of satellites in view.
- The combination of the measurements from both systems helps to reduce the system–specific variations and improve the satellite geometry in general.

PDOP: satellite geometry for ground stations

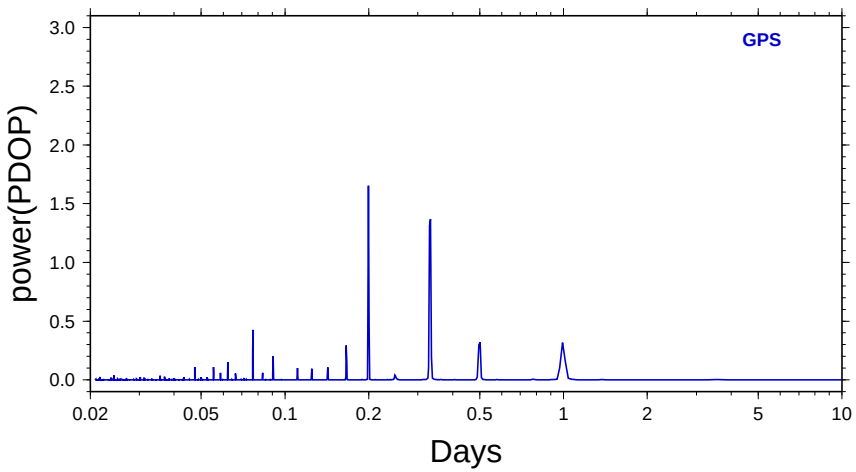
Station at the pole



Mid-latitude station

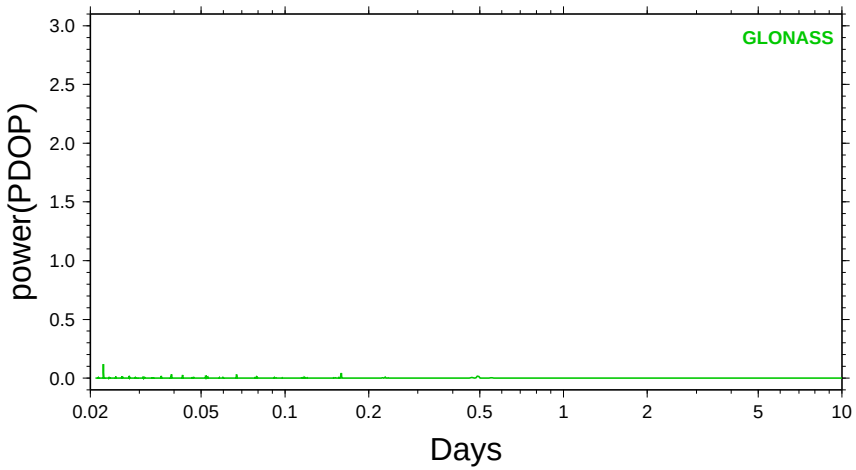


Station at the equator

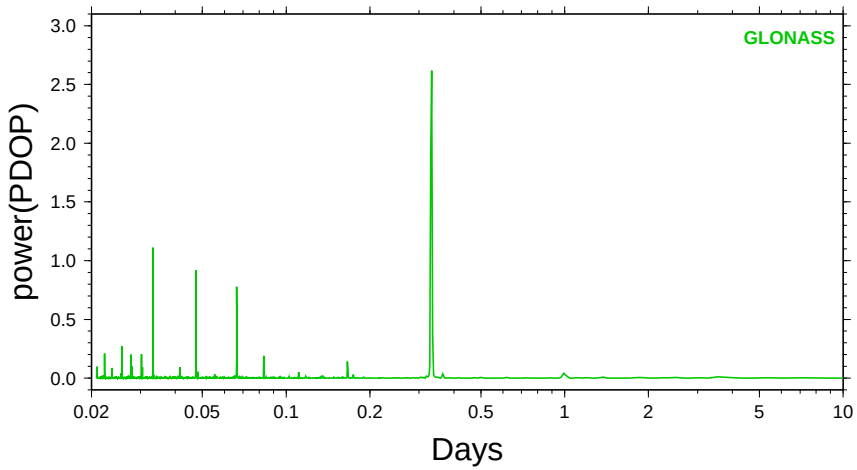


PDOP: satellite geometry for ground stations

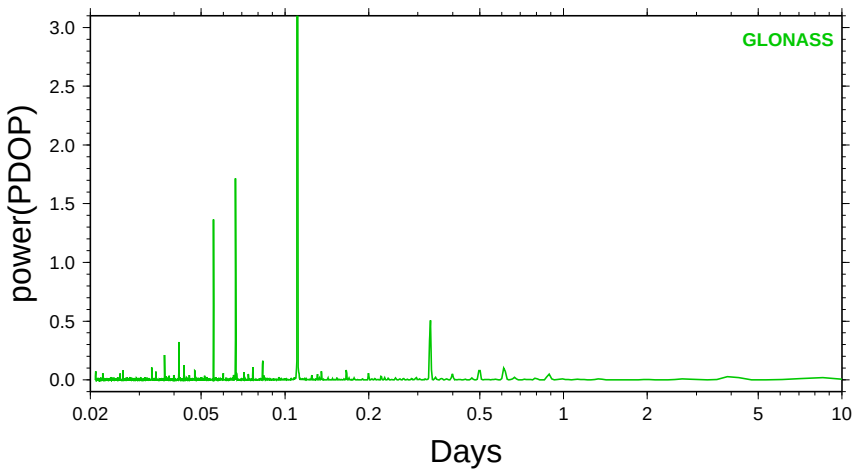
Station at the pole



Mid-latitude station

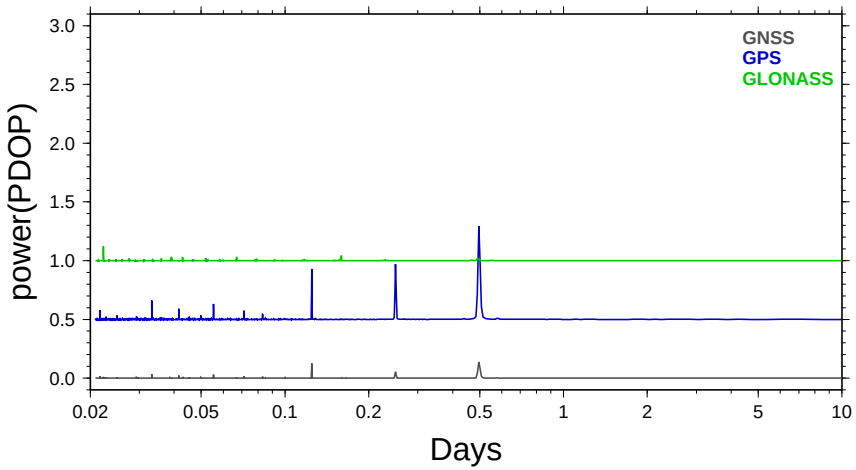


Station at the equator

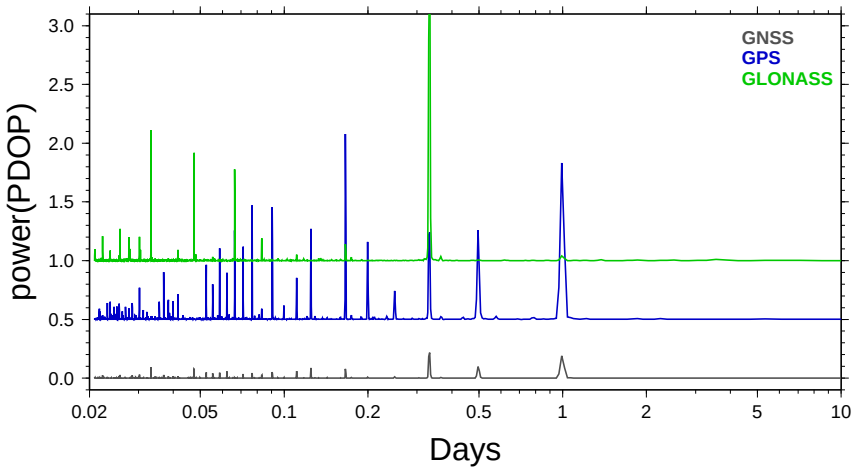


PDOP: satellite geometry for ground stations

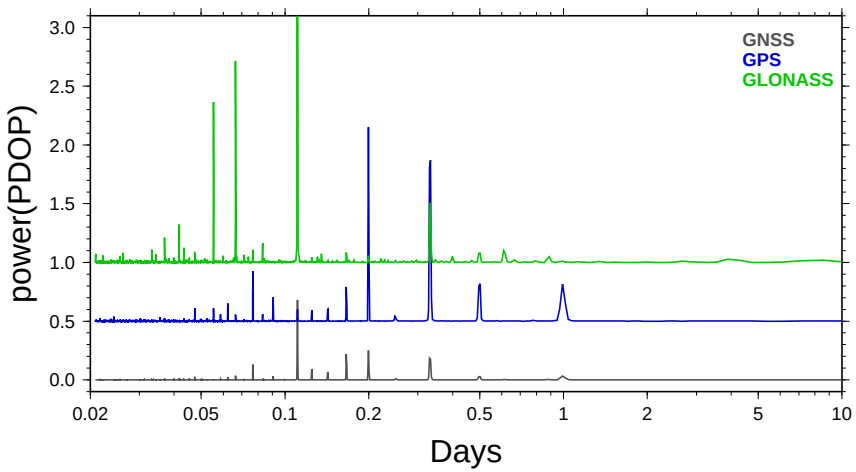
Station at the pole



Mid-latitude station



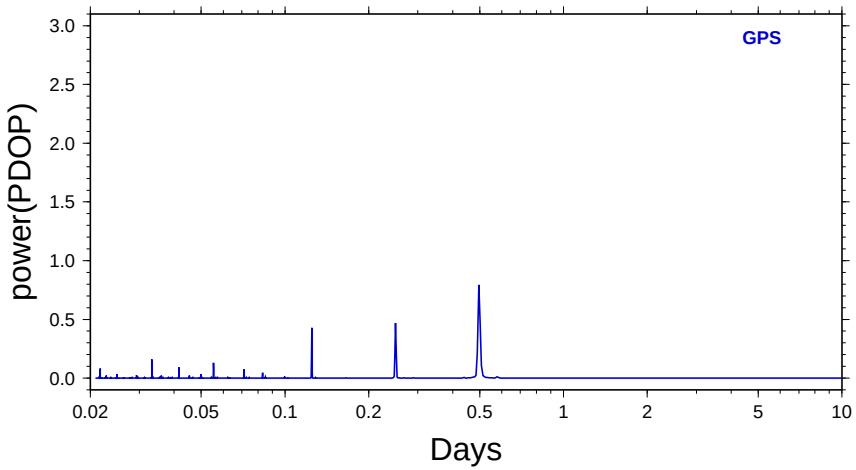
Station at the equator



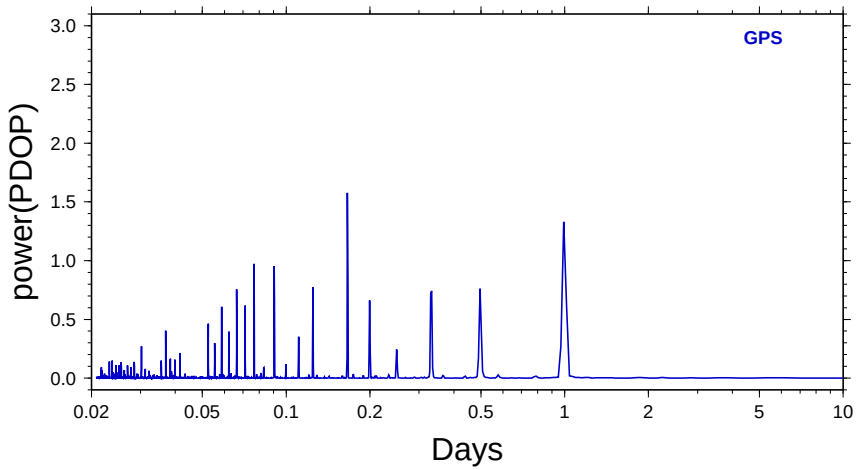
- The combination of the measurements from several systems reduces the system–specific variations in the PDOP.

PDOP: satellite geometry for ground stations

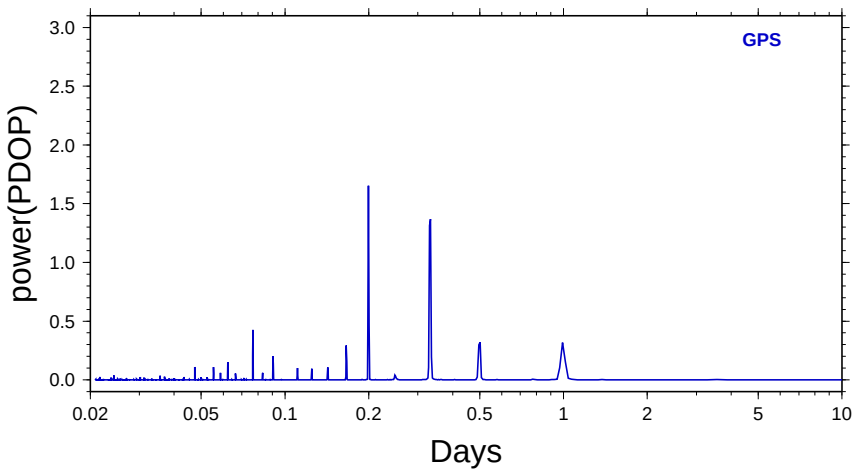
Station at the pole



Mid-latitude station



Station at the equator



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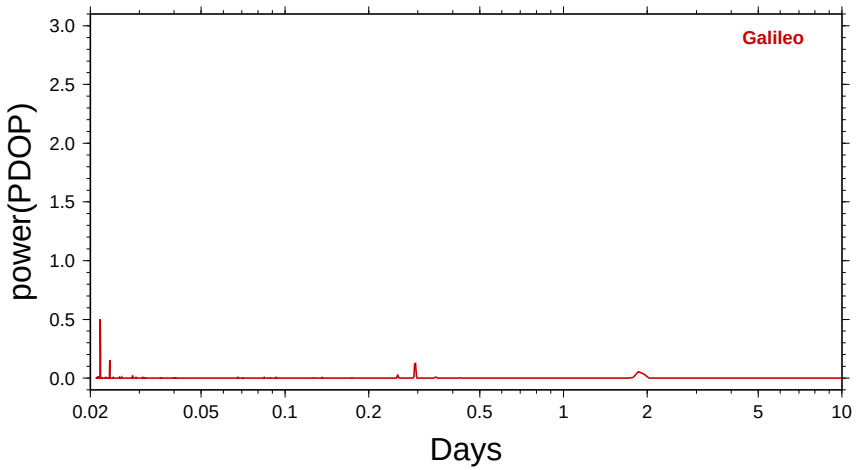
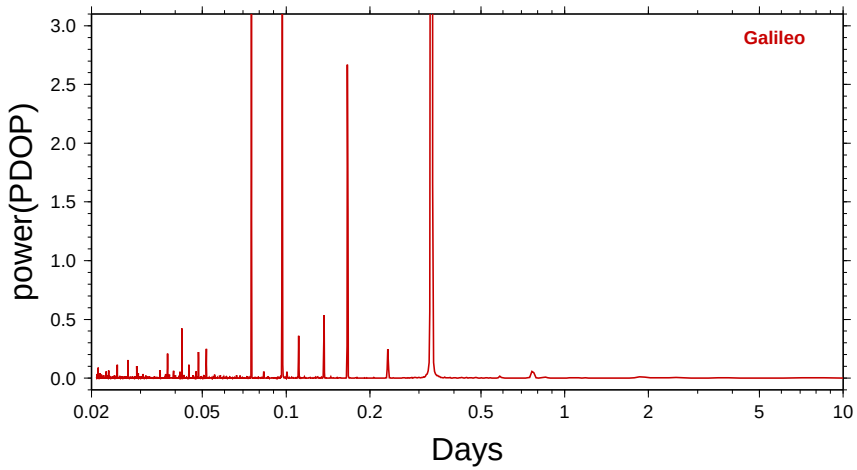
PDOP: satellite geometry for ground stations

Station at the pole



Mid-latitude station



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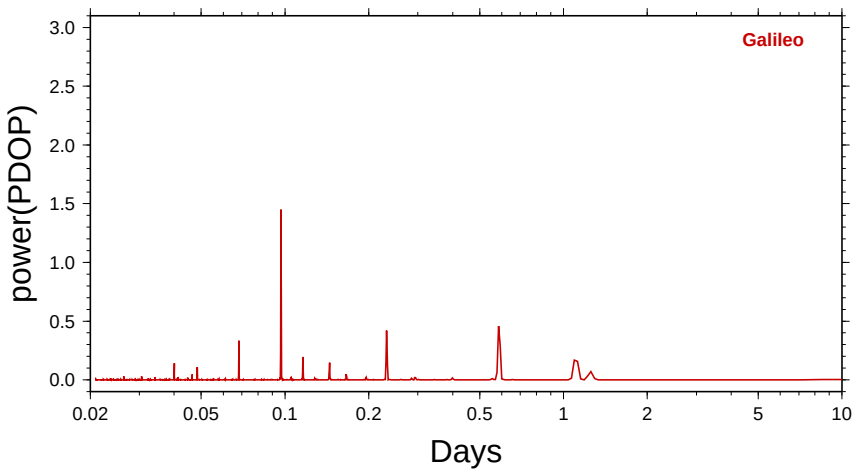

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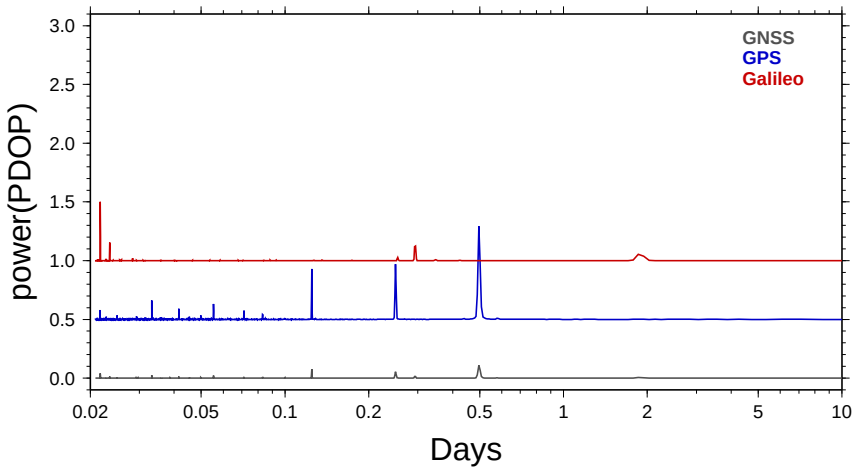
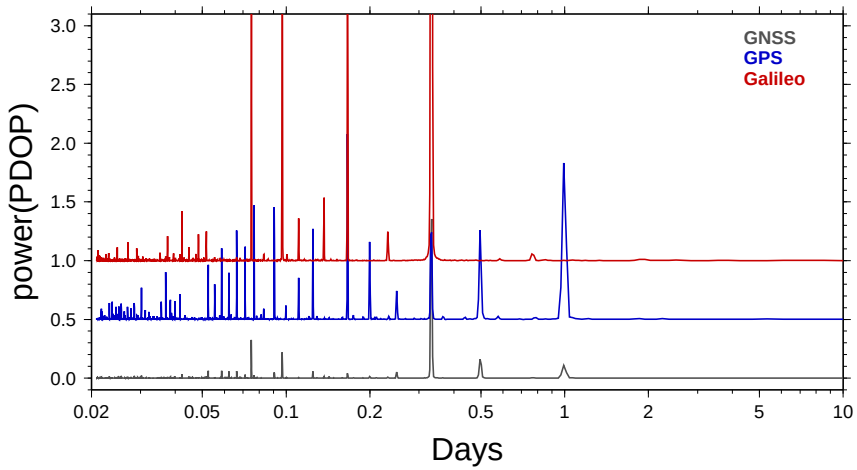
PDOP: satellite geometry for ground stations

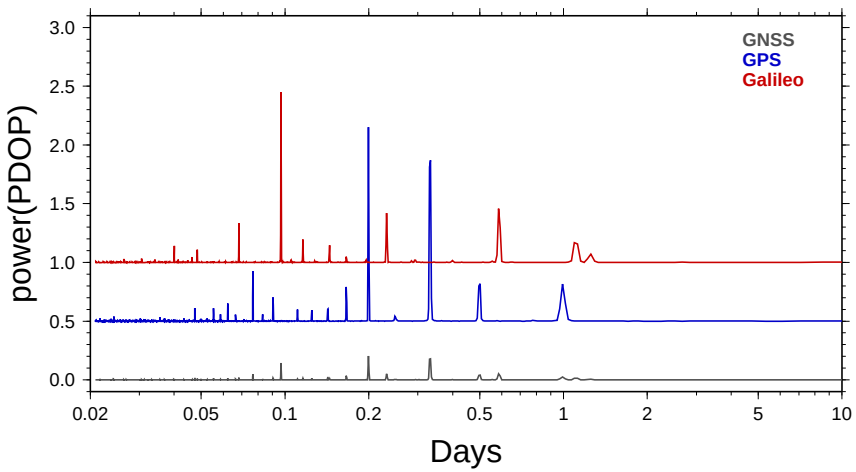
Station at the pole



Mid-latitude station



Station at the equator



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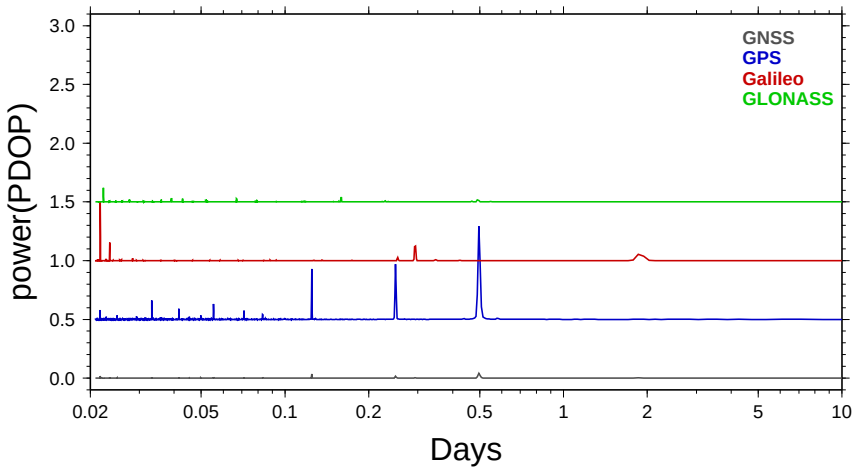
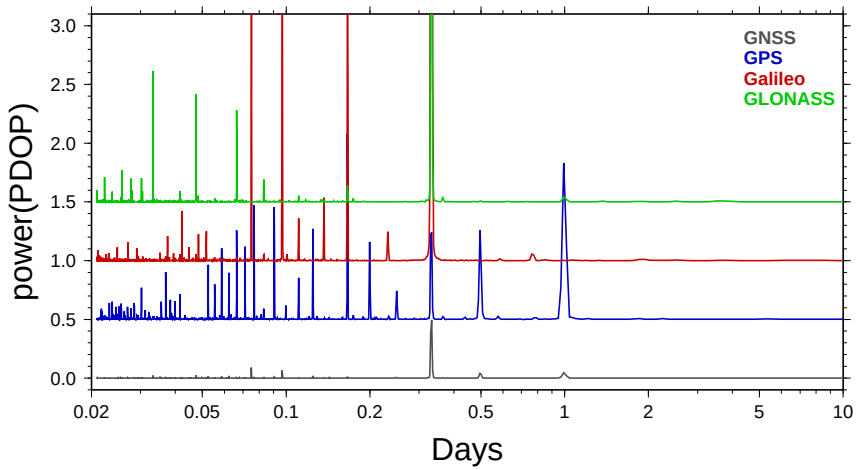
PDOP: satellite geometry for ground stations

Station at the pole



Mid-latitude station



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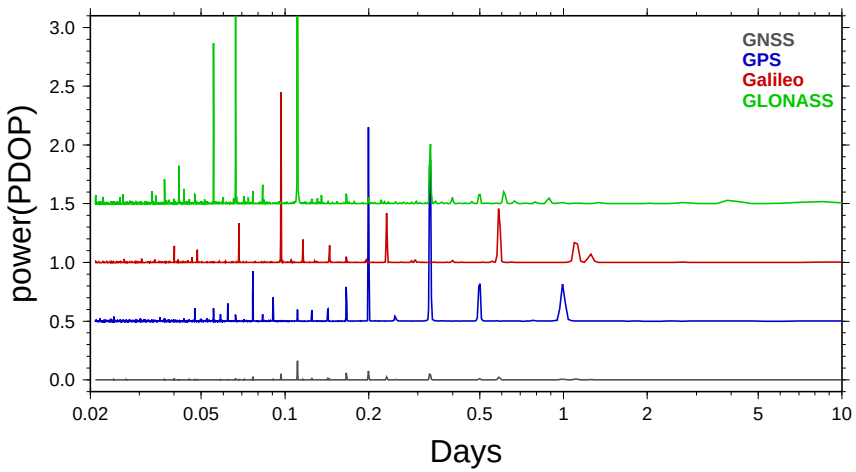

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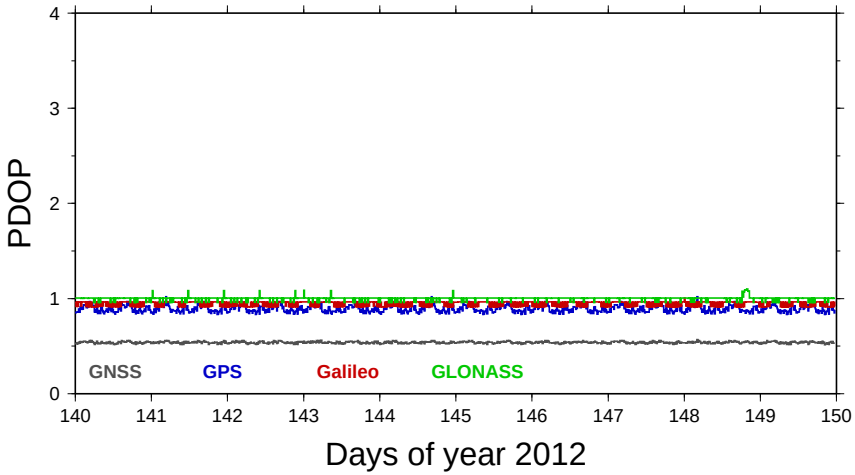
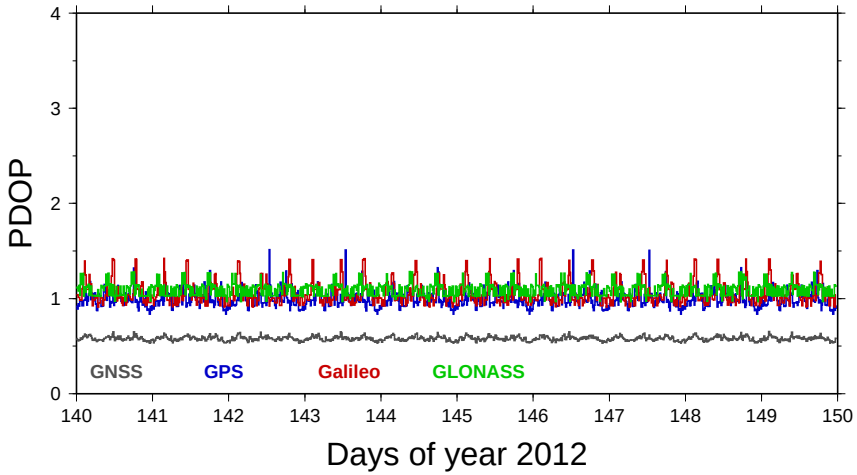
Extended positioning stability

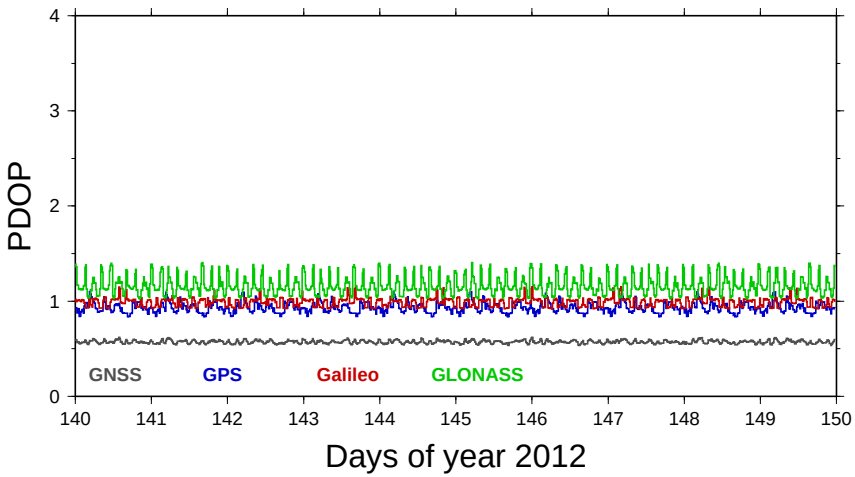
Station at the pole



Mid-latitude station



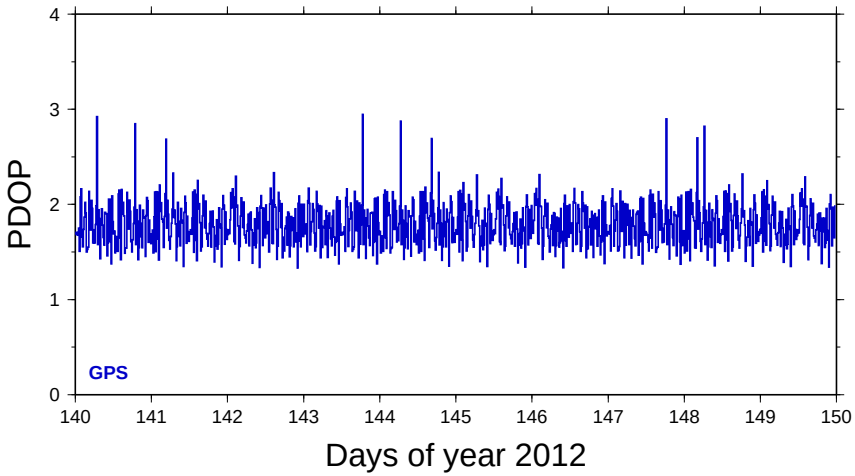
Station at the equator



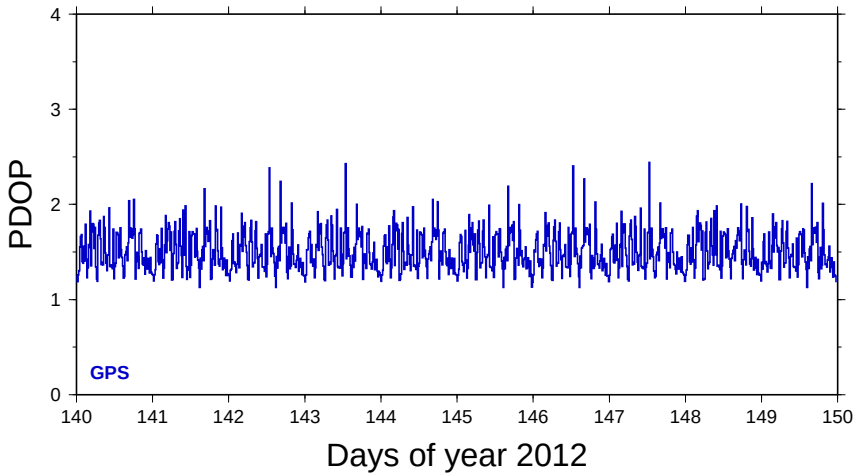
- Partials of the station coordinates are considered.

Extended positioning stability

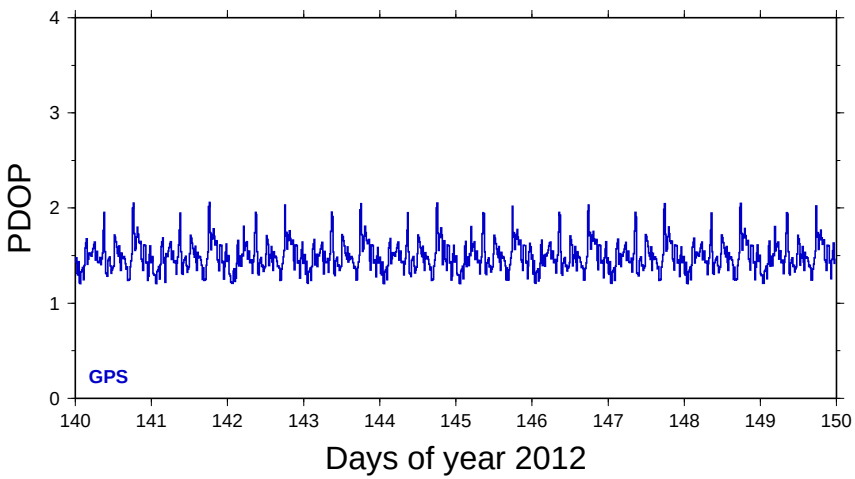
Station at the pole



Mid-latitude station



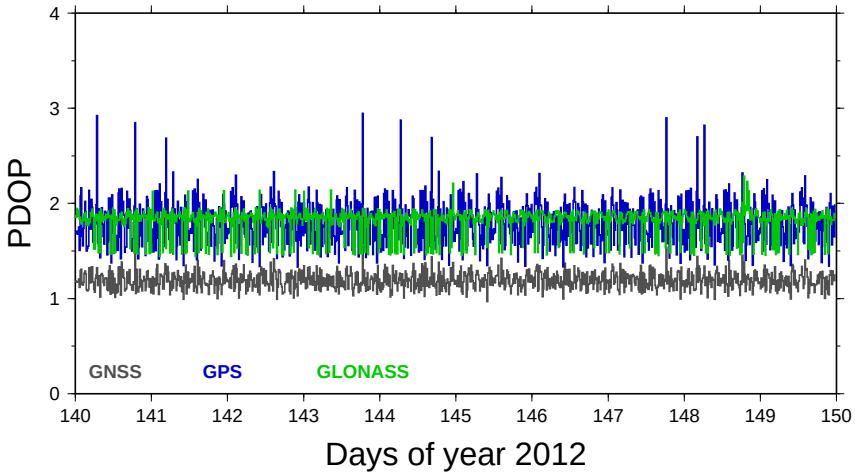
Station at the equator



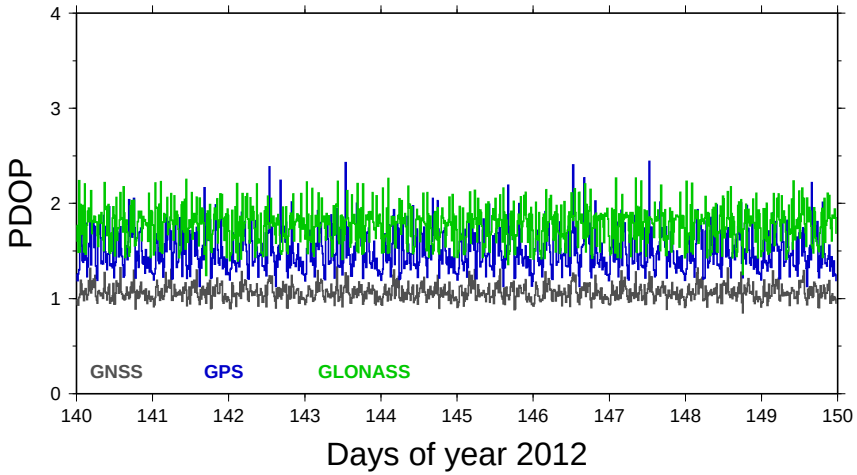
- Partials of the station coordinates and receiver clocks are considered.

Extended positioning stability

Station at the pole



Mid-latitude station



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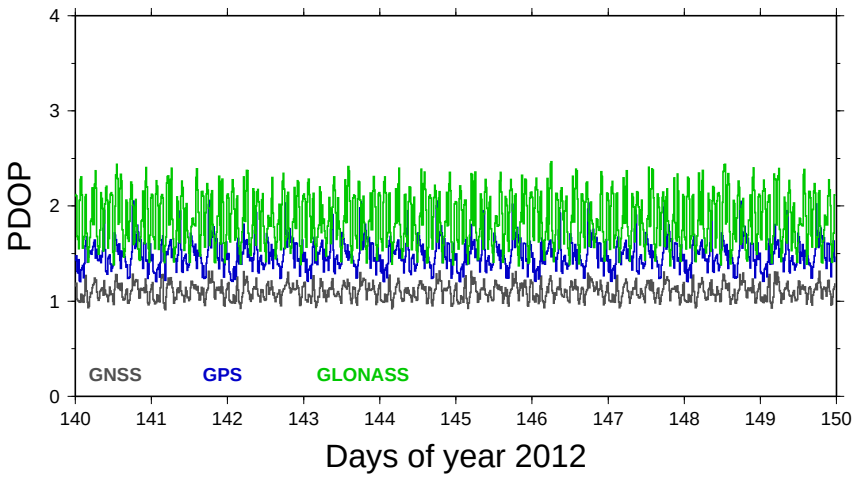

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Extended positioning stability

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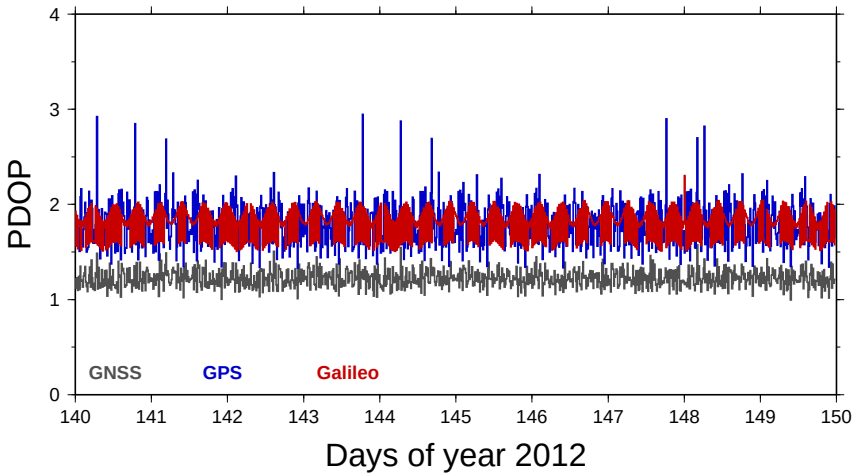

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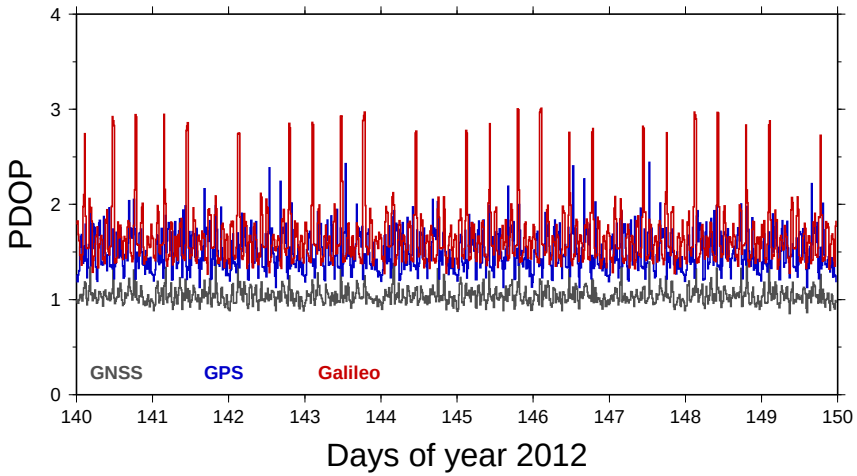

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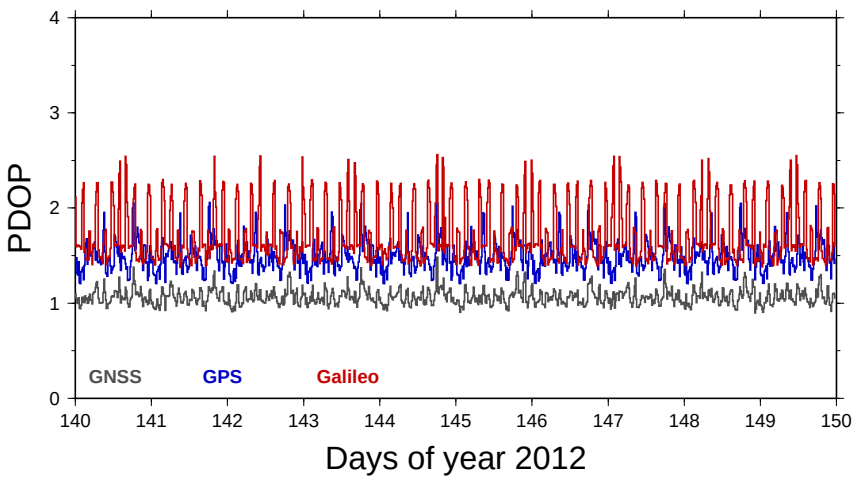

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Extended positioning stability

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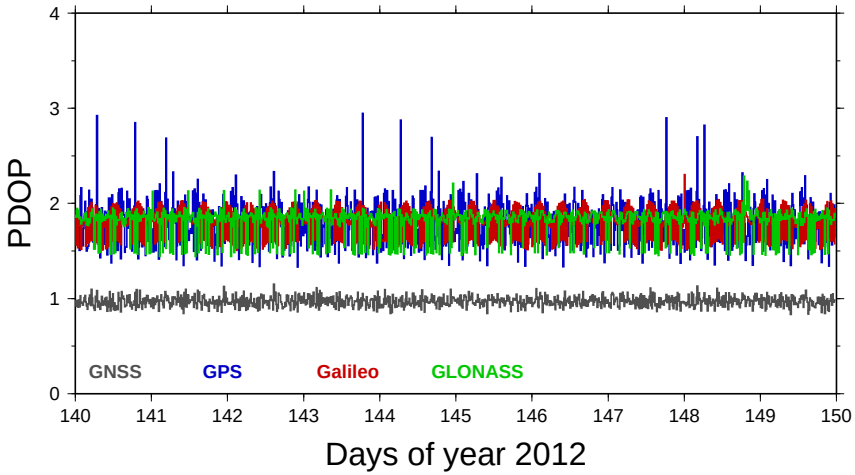

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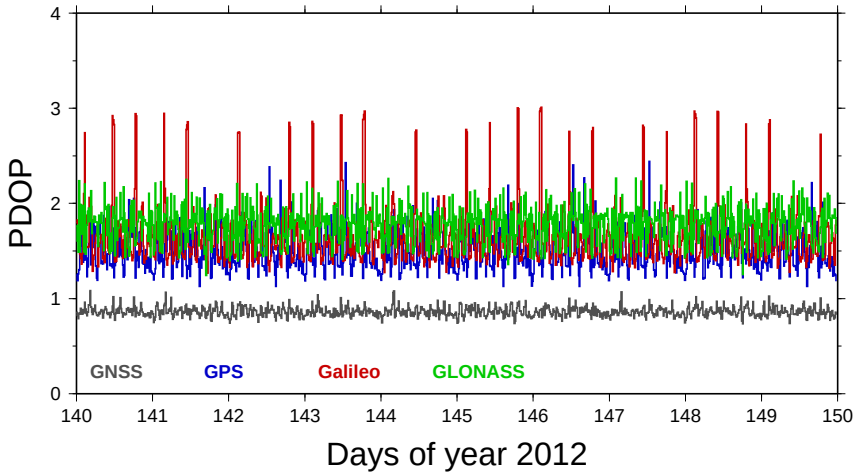
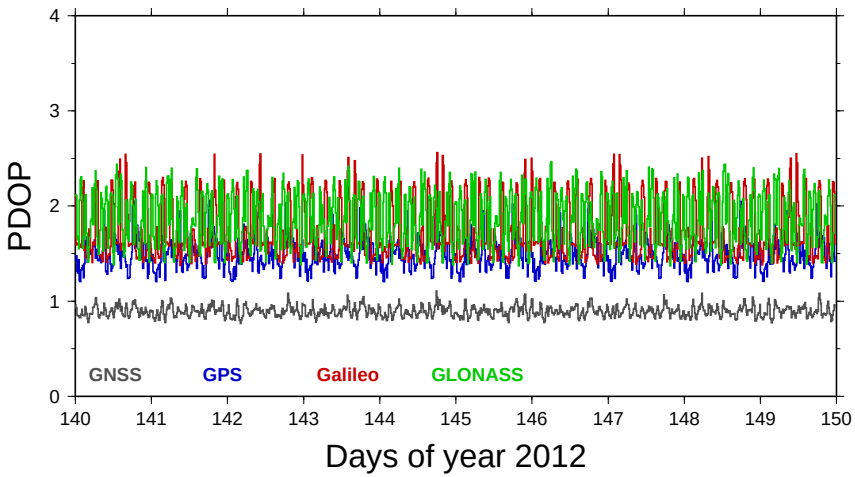


Station at the equator



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Extended positioning stability

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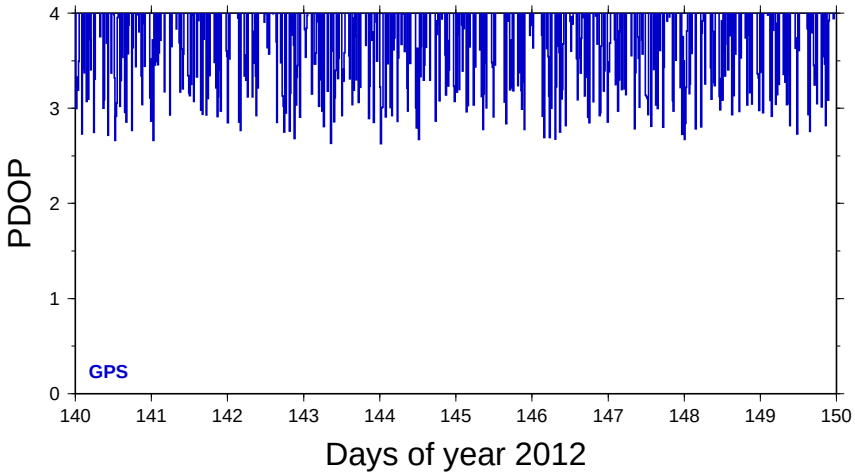
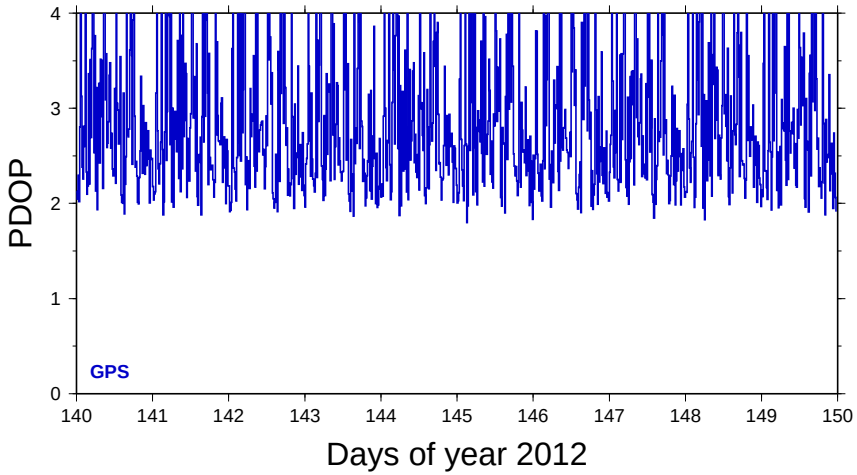
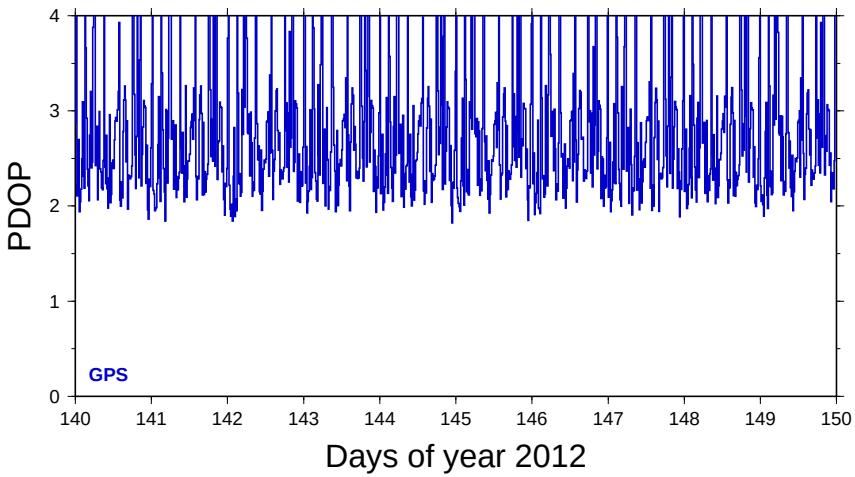


Mid-latitude station



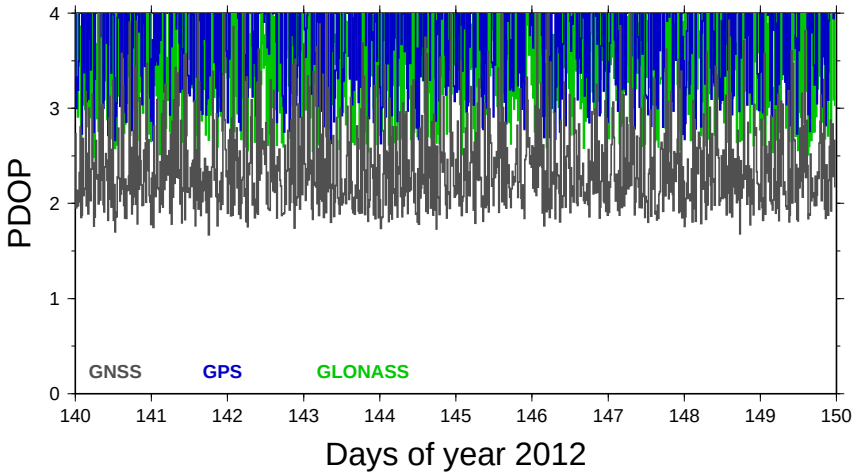
Station at the equator



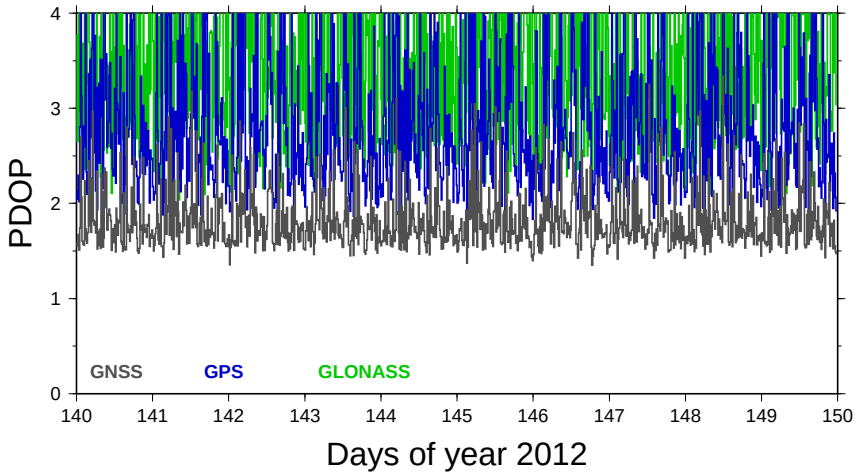
- Partials of the station coordinates, receiver clocks, and troposphere (per epoch) are considered.

Extended positioning stability

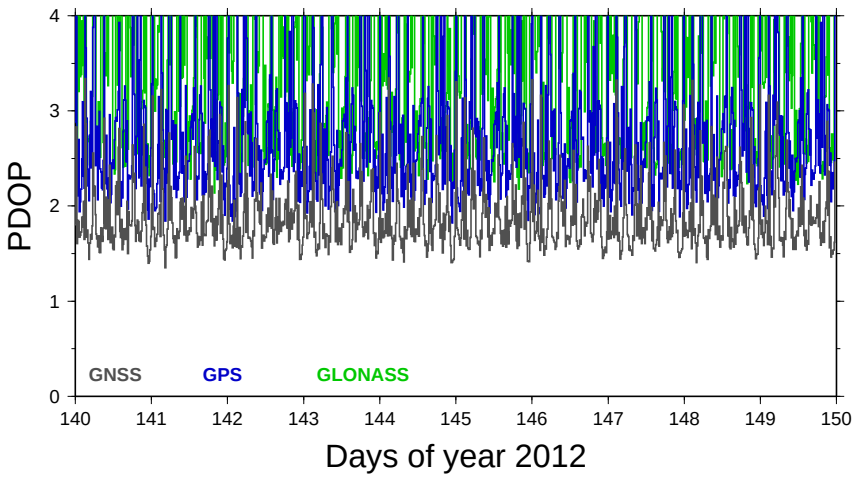
Station at the pole



Mid-latitude station



Station at the equator



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Extended positioning stability

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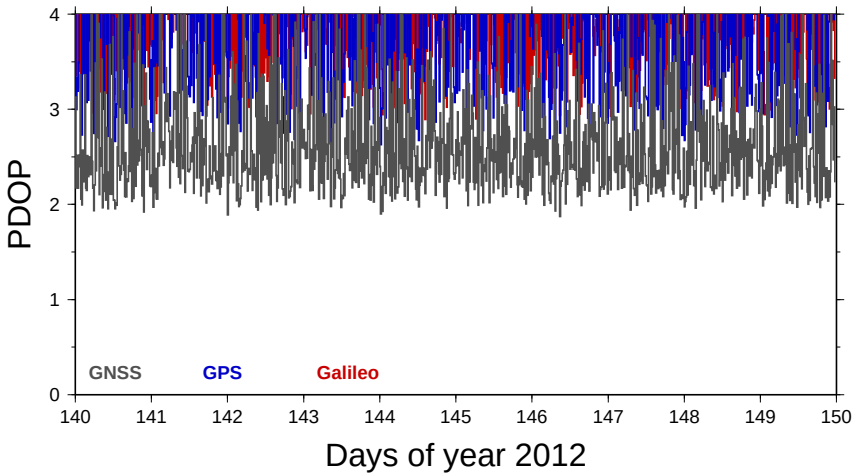

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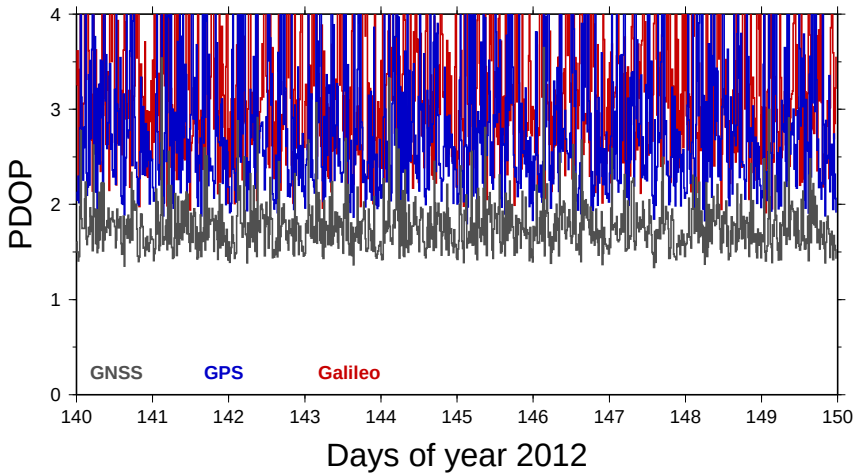

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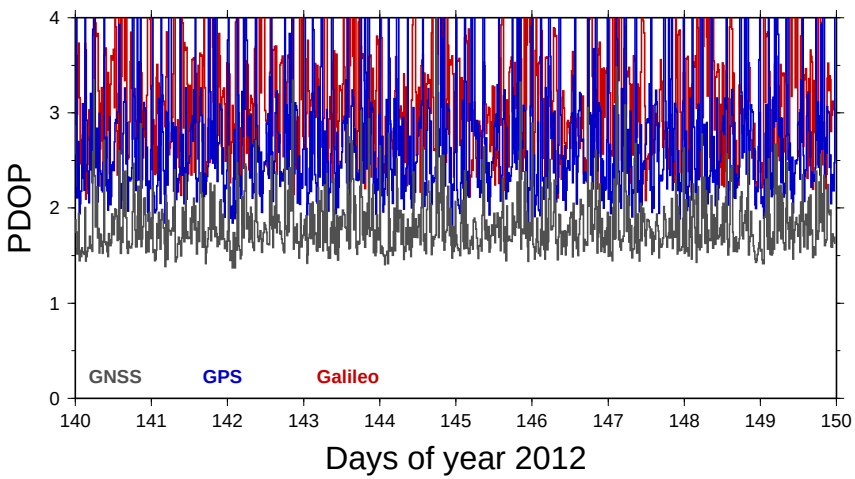

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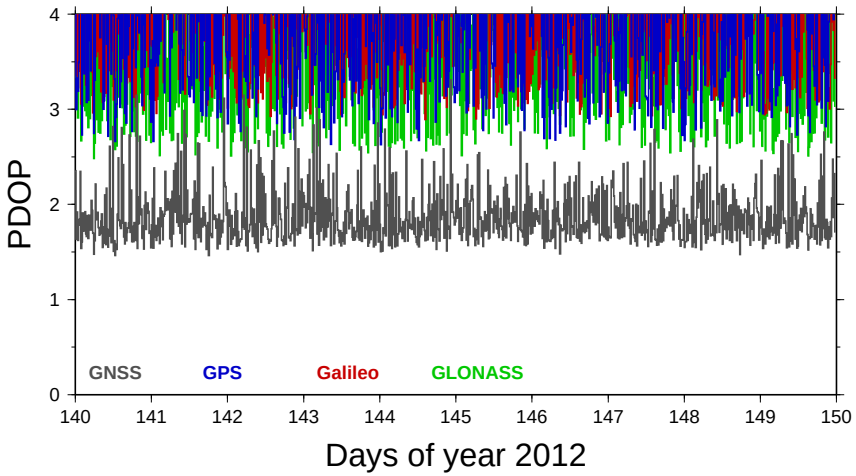
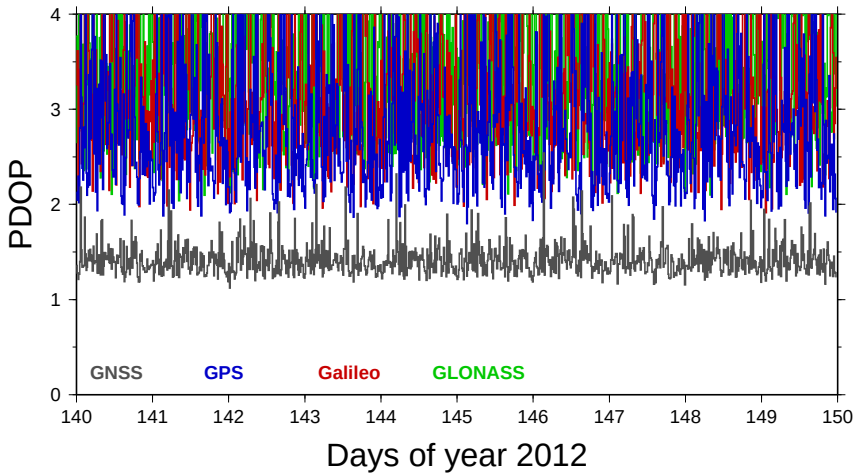
Extended positioning stability

Station at the pole



Mid-latitude station



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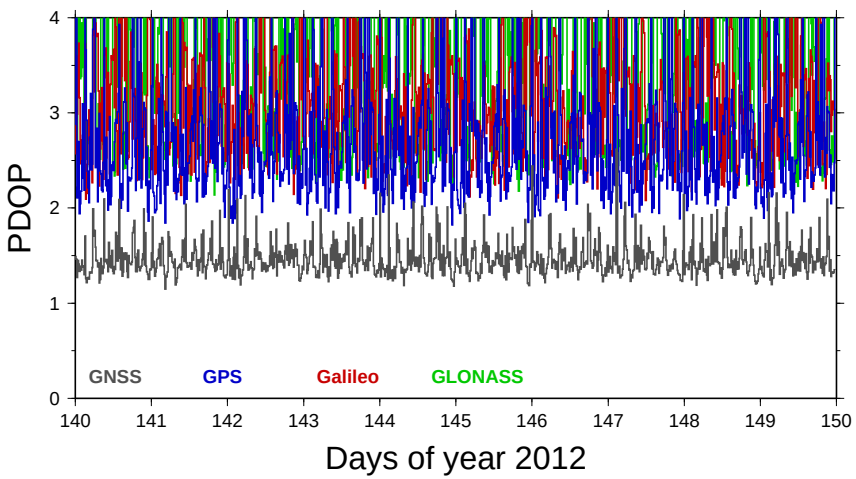

- Partials of the station coordinates, receiver clocks, and troposphere (per epoch) are considered.

Extended positioning stability

Correlation between parameters:

H_k	Height component of station k
δ_k	Receiver clock correction with respect to GPS system time at station k
Δ_{tropo_k}	Troposphere zenith path delay for station k

Extended positioning stability

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Δ_{tropo_k}	Troposphere zenith path delay for station k
h_k^i	Elevation angle for an observation at station k to satellite i

$$\frac{\partial L_k^i}{\partial H_k} = -\sin h_k^i$$

$$\frac{\partial L_k^i}{\partial \delta_k} = c$$

$$\frac{\partial L_k^i}{\partial \Delta_{\text{tropo}_k}} = \frac{1}{\sin h_k^i}$$

Extended positioning stability

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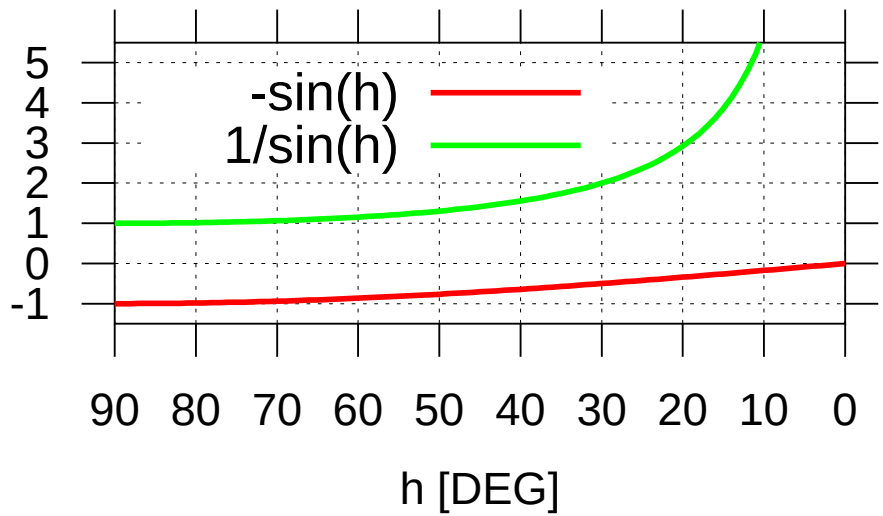

Extended positioning stability

Correlation coefficients for a station at the equator:

h_{max}	h_{min}	$\rho(H_k, \Delta_{\text{tropo}_k})$	$\rho(H_k, \delta_k)$	$\rho(\Delta_{\text{tropo}_k}, \delta_k)$
90 °	5 °	-0.802	0.949	-0.907
90 °	10 °	-0.907	0.975	-0.968
90 °	15 °	-0.943	0.985	-0.983
90 °	20 °	-0.964	0.990	-0.990

Correlation coefficients for a station at the pole:

h_{max}	h_{min}	$\rho(H_k, \Delta_{\text{tropo}_k})$	$\rho(H_k, \delta_k)$	$\rho(\Delta_{\text{tropo}_k}, \delta_k)$
45 °	5 °	-0.868	0.967	-0.946
45 °	10 °	-0.937	0.984	-0.980
45 °	15 °	-0.967	0.992	-0.990
45 °	20 °	-0.983	0.996	-0.995

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  (Keywords: different types of code measurements; quarter–cycle)

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- We have to consider the consistently combined processing of measurements from different GNSS.
  - challenge for science and research
  - simply more observations become available (beneficial in particular for kinematic applications)

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- We have to consider the consistently combined processing of measurements from different GNSS.
- Let us start in the new and colorful world with several GNSS, multiple signals:
  The future has started!

THANK YOU
for your attention

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