Impact of troposphere modeling on GNSS satellite antenna phase center pattern estimation

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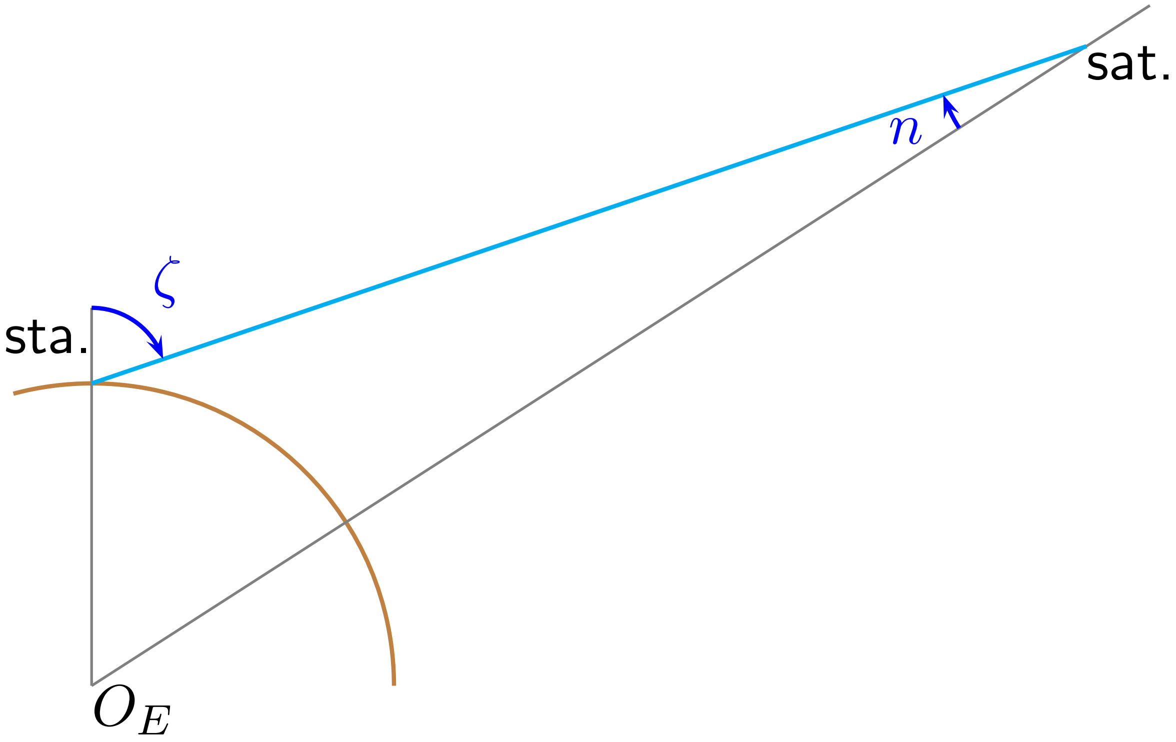
Relation between elevation and nadir angle



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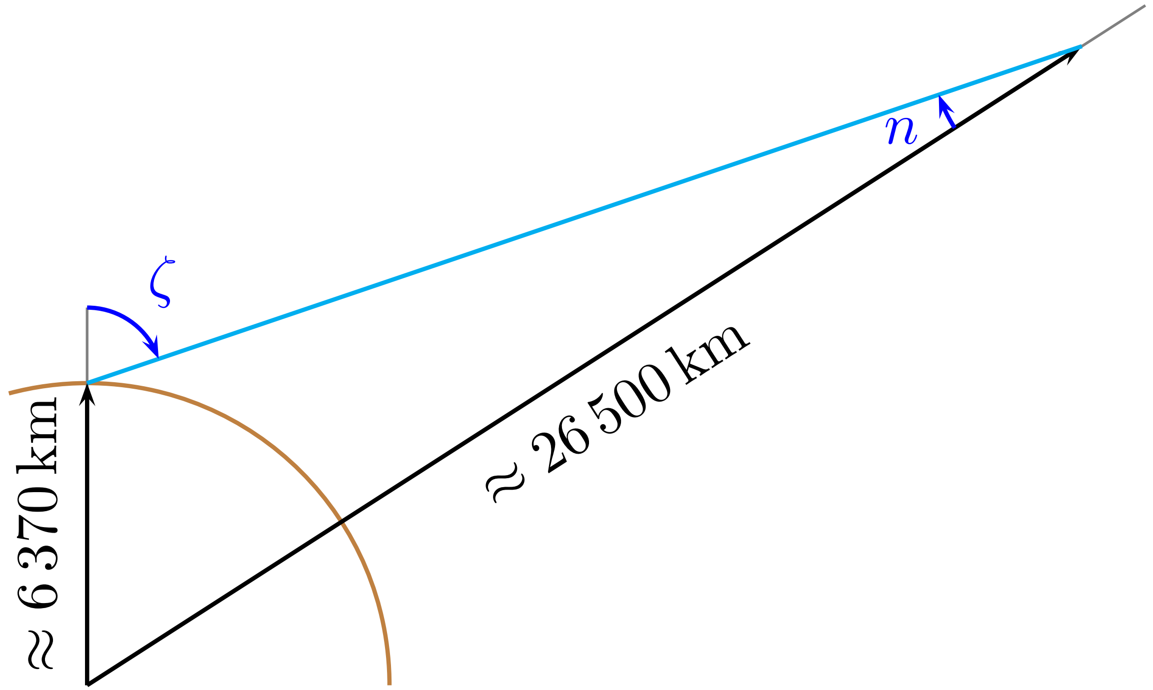

ζ	n_{GPS}
0	0.0
10	2.4
20	4.7
30	6.9
40	8.8
50	10.6
60	11.9
70	12.9
80	13.6
90	13.8

Values given in degree.

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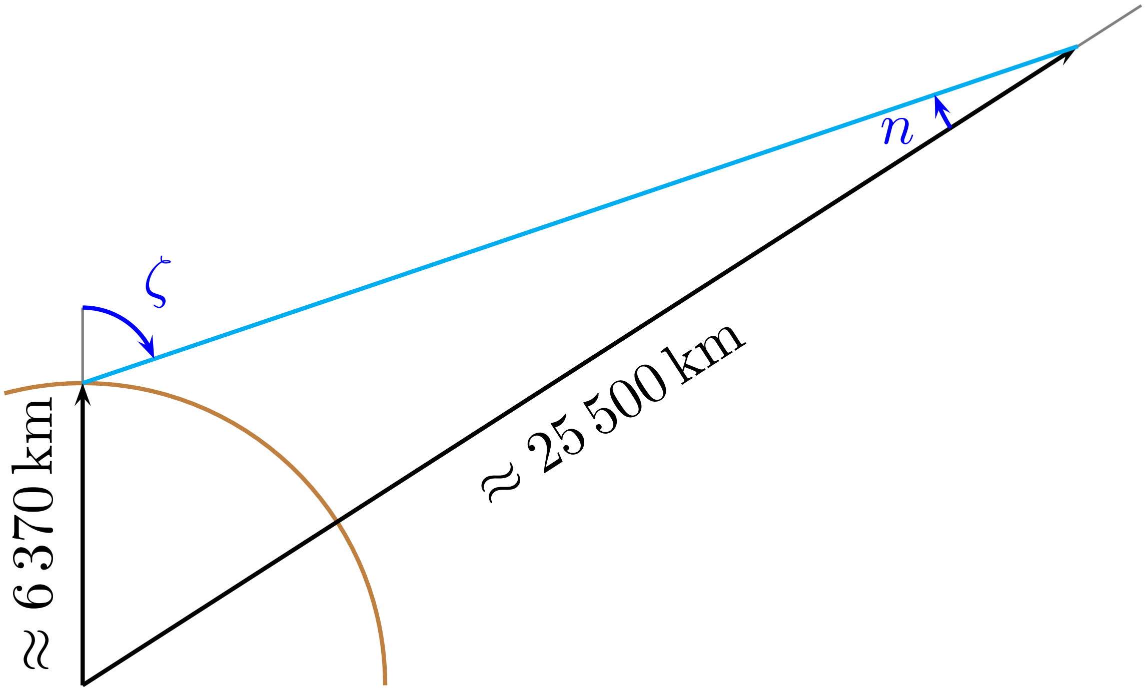

ζ	n_{GPS}	n_{GLO}
0	0.0	0.0
10	2.4	2.5
20	4.7	4.9
30	6.9	7.2
40	8.8	9.2
50	10.6	11.0
60	11.9	12.4
70	12.9	13.4
80	13.6	14.1
90	13.8	14.3

Values given in degree.

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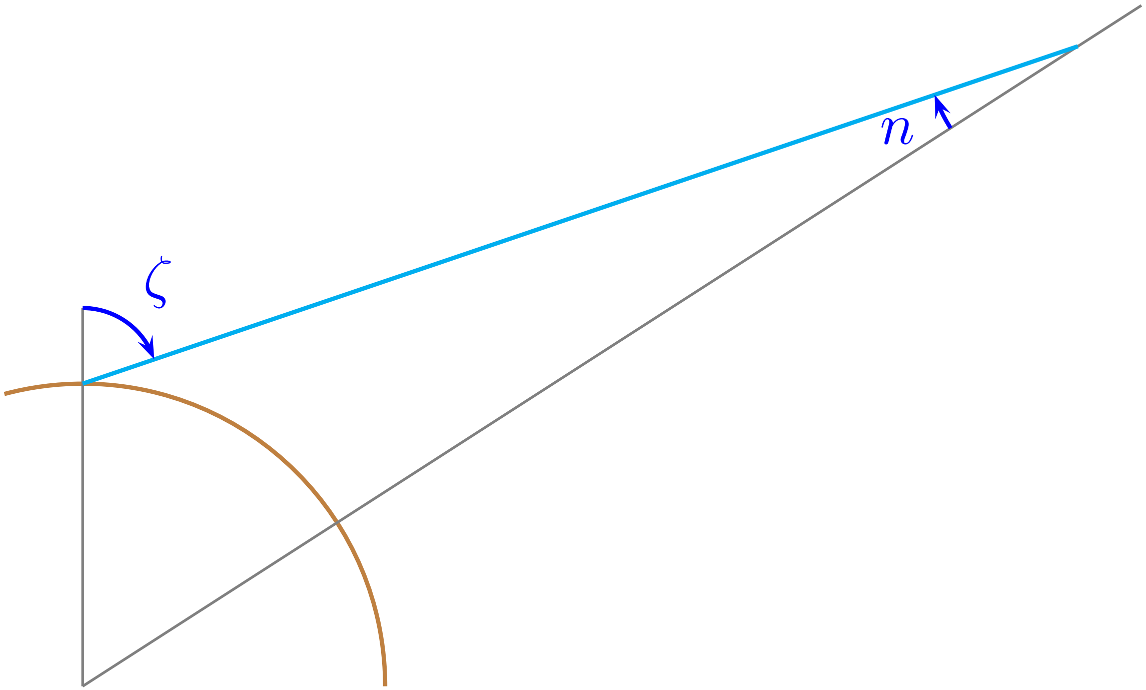

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Values given in degree.

A zenith–angle–dependent bias in the troposphere model may be compensated by the estimated satellite antenna phase center pattern.

Situation in case of IGS08.ATX

IGS08.ATX	Satellite antenna phase center pattern	Satellite antenna phase center offset
GPS	**from** IGS05.ATX (GFZ,TUM) **NMF**	**from repro1 and final** (CODE,ESA,GFZ,MIT,NRCan) **GMF**

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Situation in case of IGS08.ATX

IGS08.ATX	Satellite antenna phase center: pattern	Satellite antenna phase center: offset
GPS	**from** IGS05.ATX (GFZ,TUM) **NMF**	**from repro1 and final** (CODE,ESA,GFZ,MIT,NRCan) **GMF**
GLONASS	**from GLONASS–repro** (CODE,ESA) **GMF**	**from GLONASS–repro** (CODE,ESA) **GMF**

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GPS	**from** `IGS05.ATX` (GFZ,TUM) **NMF**	**from repro1 and final** (CODE,ESA,GFZ,MIT,NRCan) **GMF**
GPS IIF	**from GLONASS–repro** (CODE,ESA) **GMF**	**from GLONASS–repro** (CODE,ESA) **GMF**
GLONASS	**from GLONASS–repro** (CODE,ESA) **GMF**	**from GLONASS–repro** (CODE,ESA) **GMF**

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CODE has started to use **VMF1** for its operational final and rapid products in October 2010.

Questions

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- Which solution compares best with a LEO–derived solution? (independent from troposphere model)

Questions

How does the satellite antenna phase center model depend on the troposphere model for the ground stations?

- How do different troposphere models affect the satellite antenna phase center?

- Which solution compares best with a LEO–derived solution? (independent from troposphere model)

- What is the impact on ground stations, if the troposphere model is inconsistent with the satellite antenna phase center model?

Three solution series for two years: 2009 and 2010

- observation files $\longrightarrow$ weekly normal equation file
  implicit: satellite orbits, troposphere parameters, Earth rotation parameters
  explicit: coordinates, satellite antenna phase center offsets and patterns
  `IGS08.ATX` for receiver antenna phase center corrections
  3° elevation mask (in fact: 5°)

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- series with different troposphere models:

VMF1:	Vienna Mapping Function	ECMWF	(Böhm et al., 2006)
GMF:	Global Mapping Function	GPT	(Böhm et al., 2006)
NMF:	Niell Mapping Function	Berg, 1947	(Niell, 1996)

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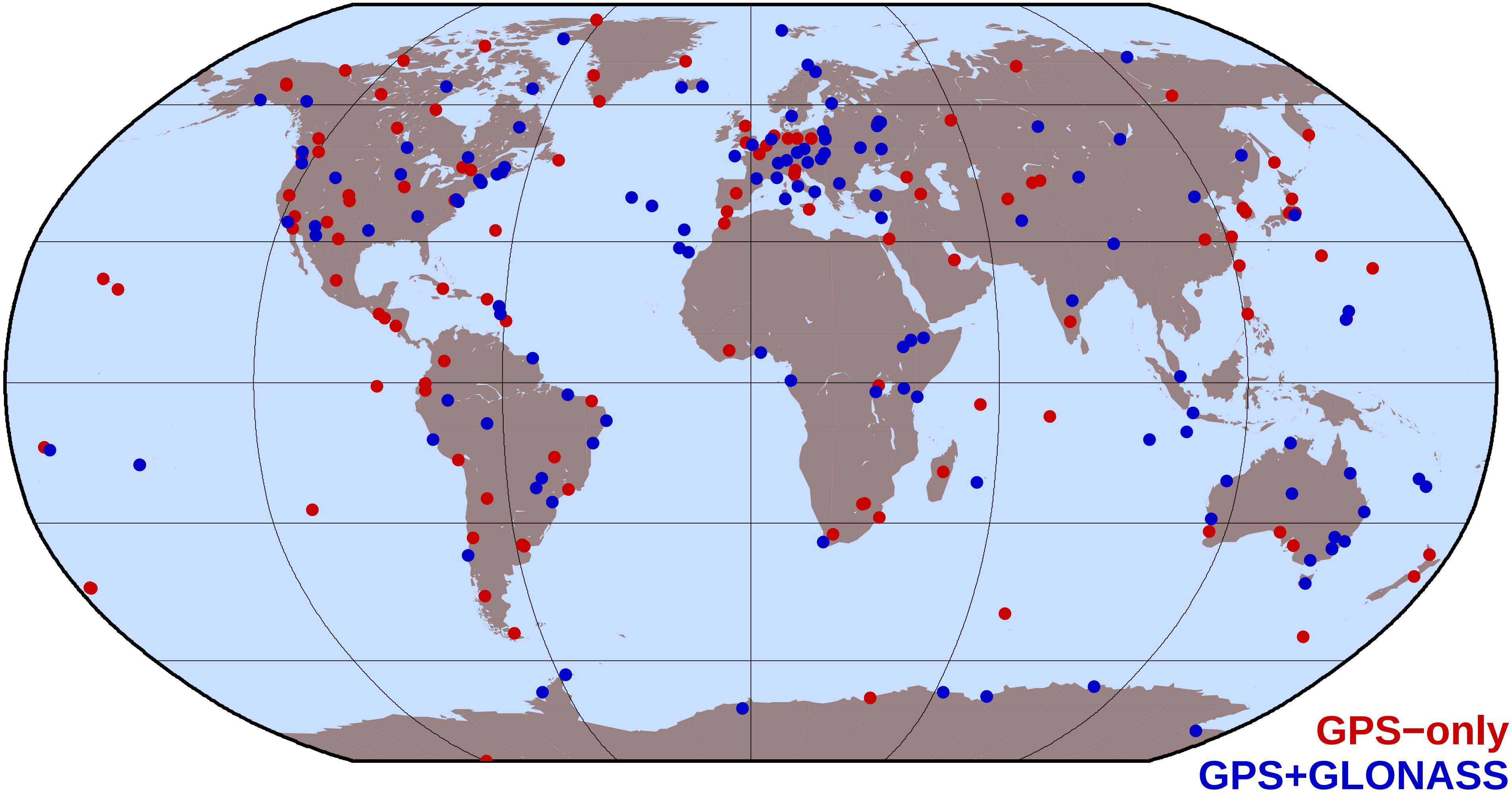
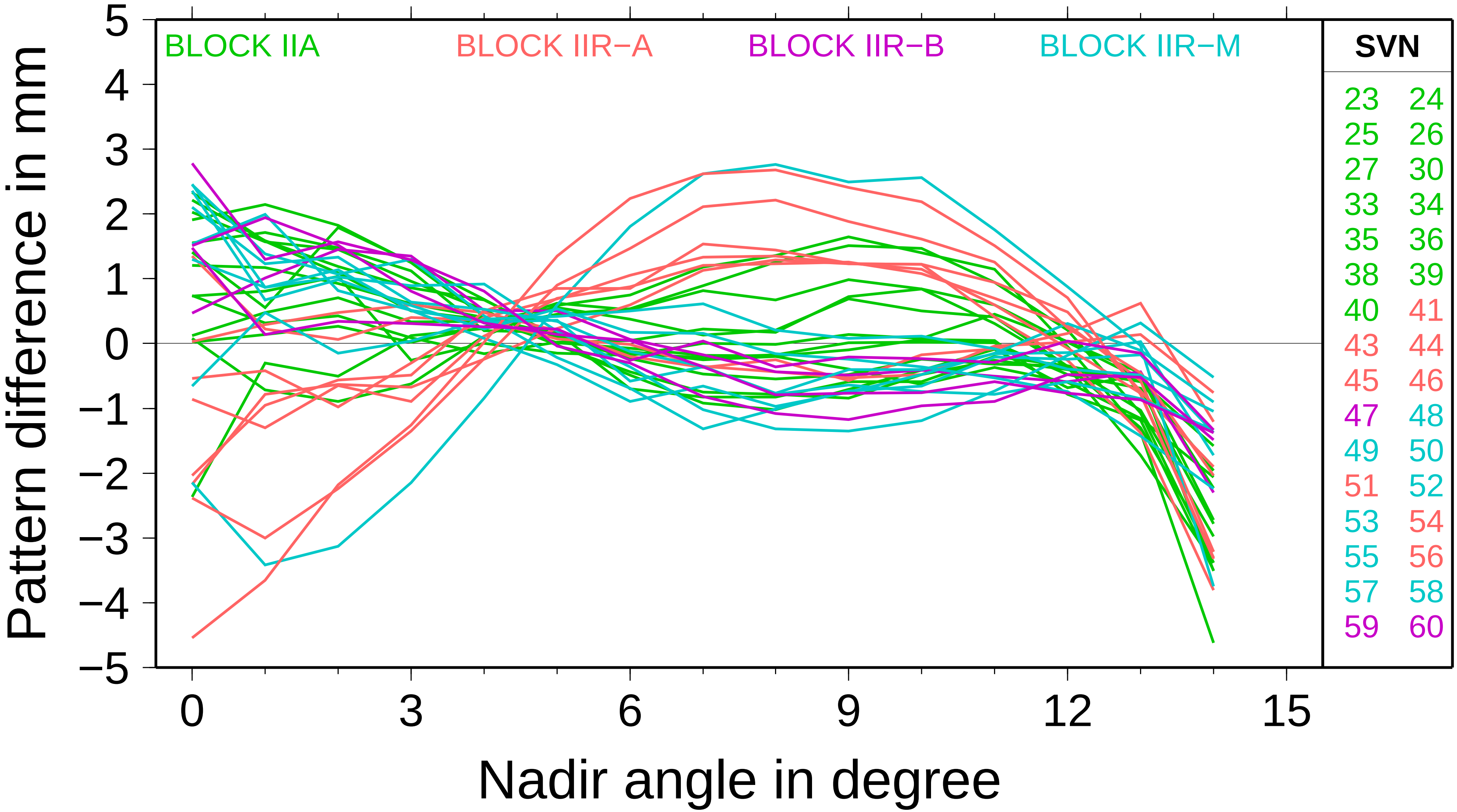
- The cumulative solution has been computed using identical datum stations and same solution intervals:
  minimum constraint solution w.r.t. IGS08 frame

Three solution series for two years: 2009 and 2010



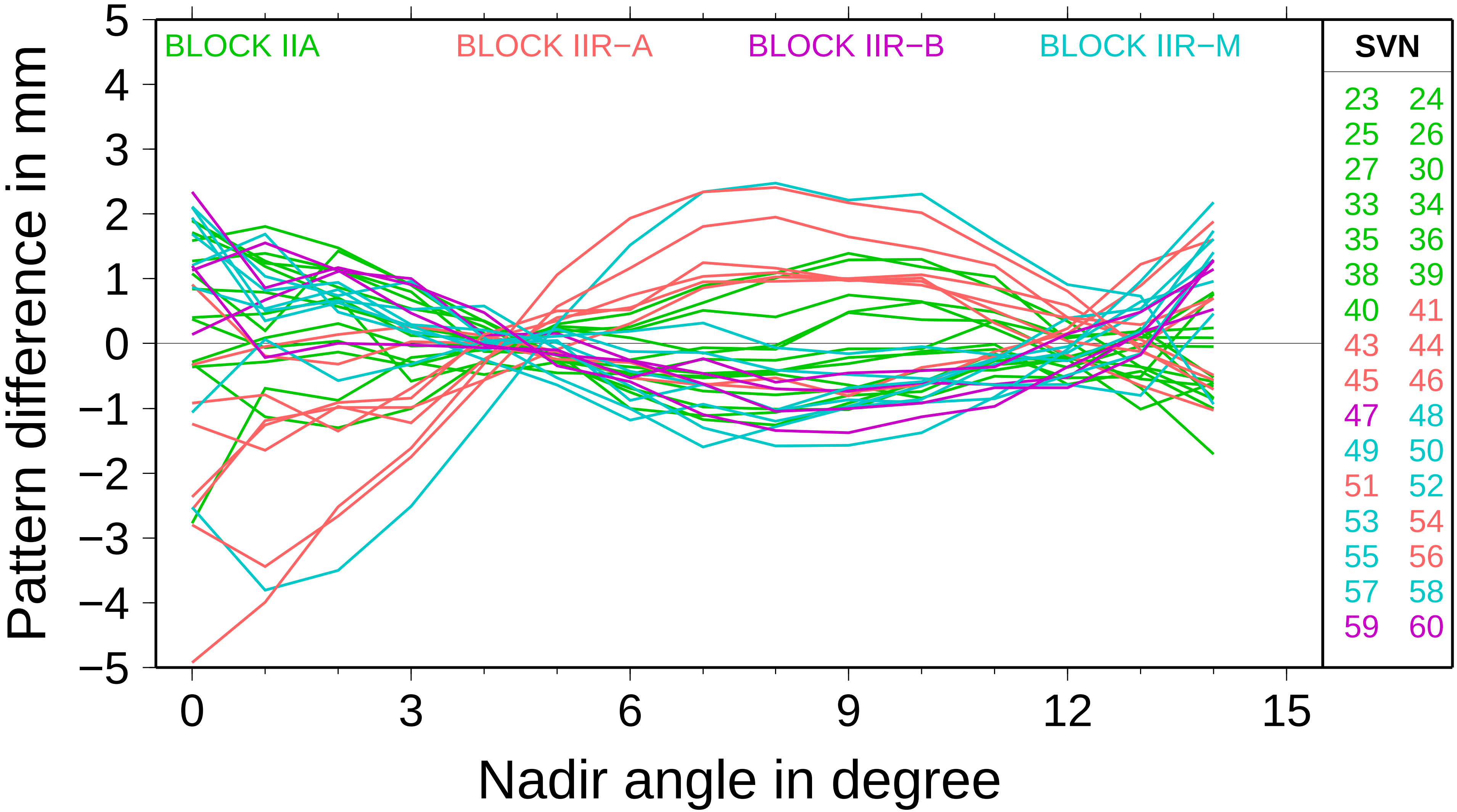
Satellite antenna phase center patterns, GPS

Differences between NMF–based estimates and IGS08.ATX values



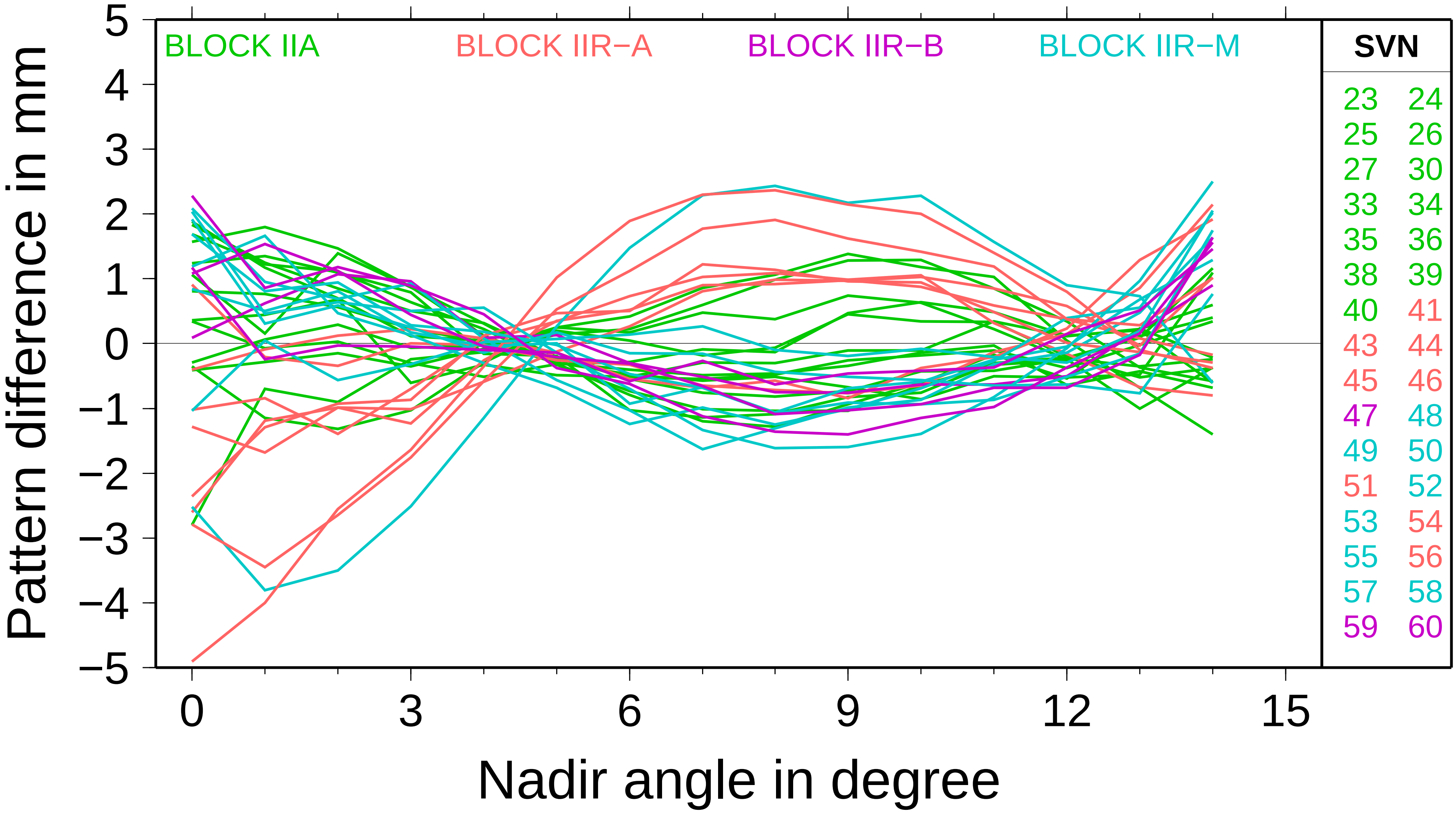
Satellite antenna phase center patterns, GPS

Differences between GMF–based estimates and `IGS08.ATX` values



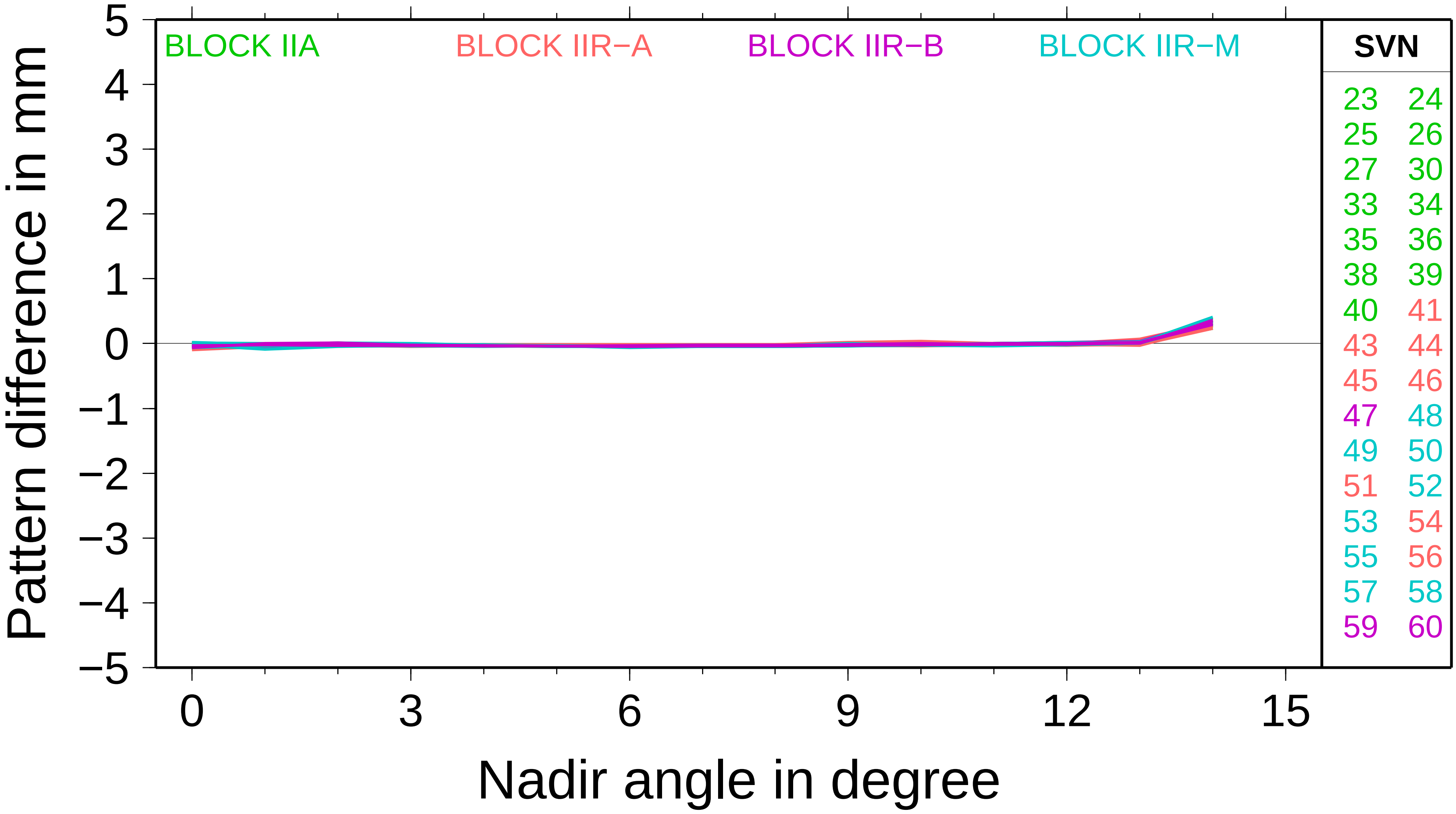
Satellite antenna phase center patterns, GPS

Differences between VMF1–based estimates and `IGS08.ATX` values



Satellite antenna phase center patterns, GPS

Differences between VMF1– and GMF–based estimates



Satellite antenna phase center patterns, GPS

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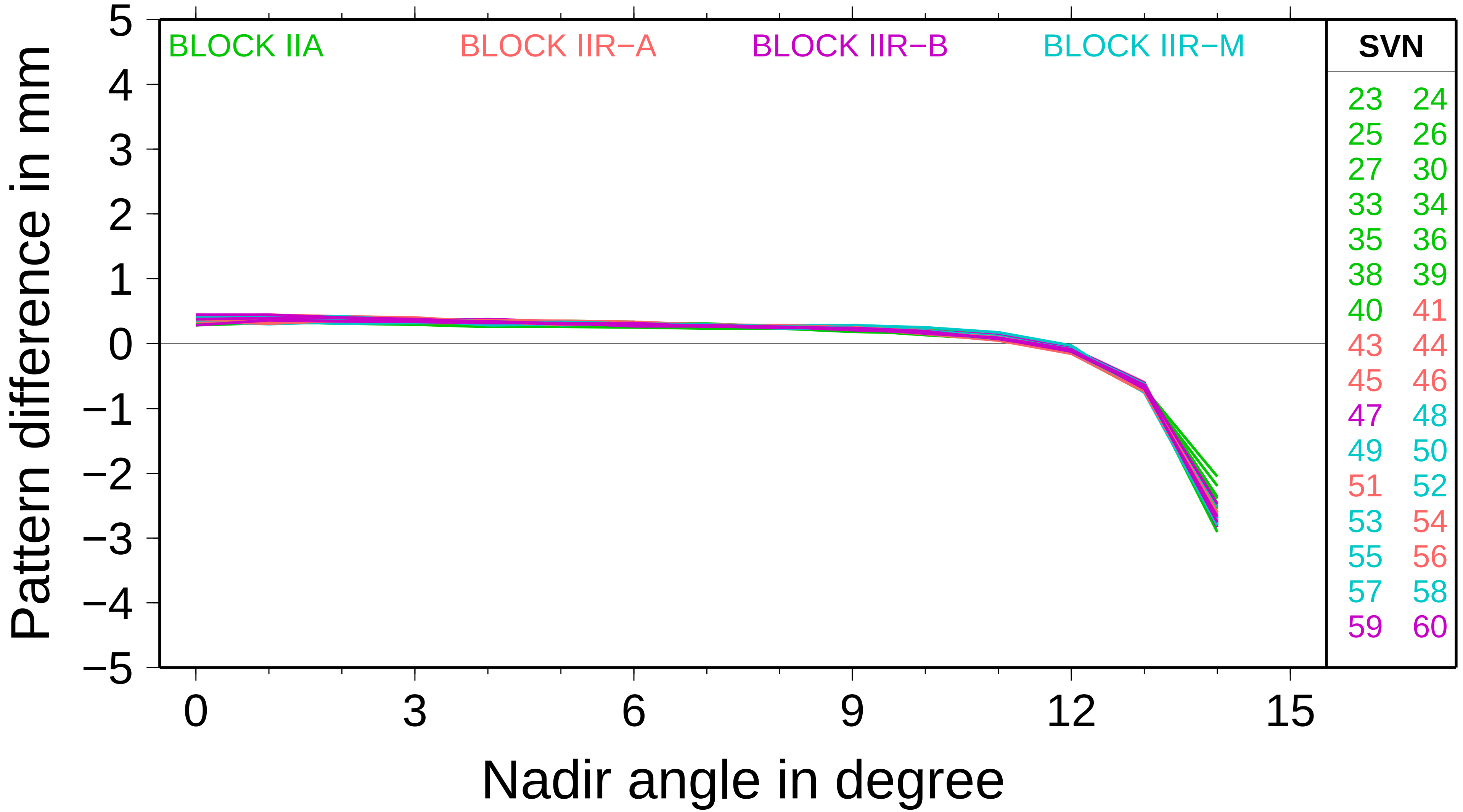

Satellite antenna phase center patterns, GLONASS

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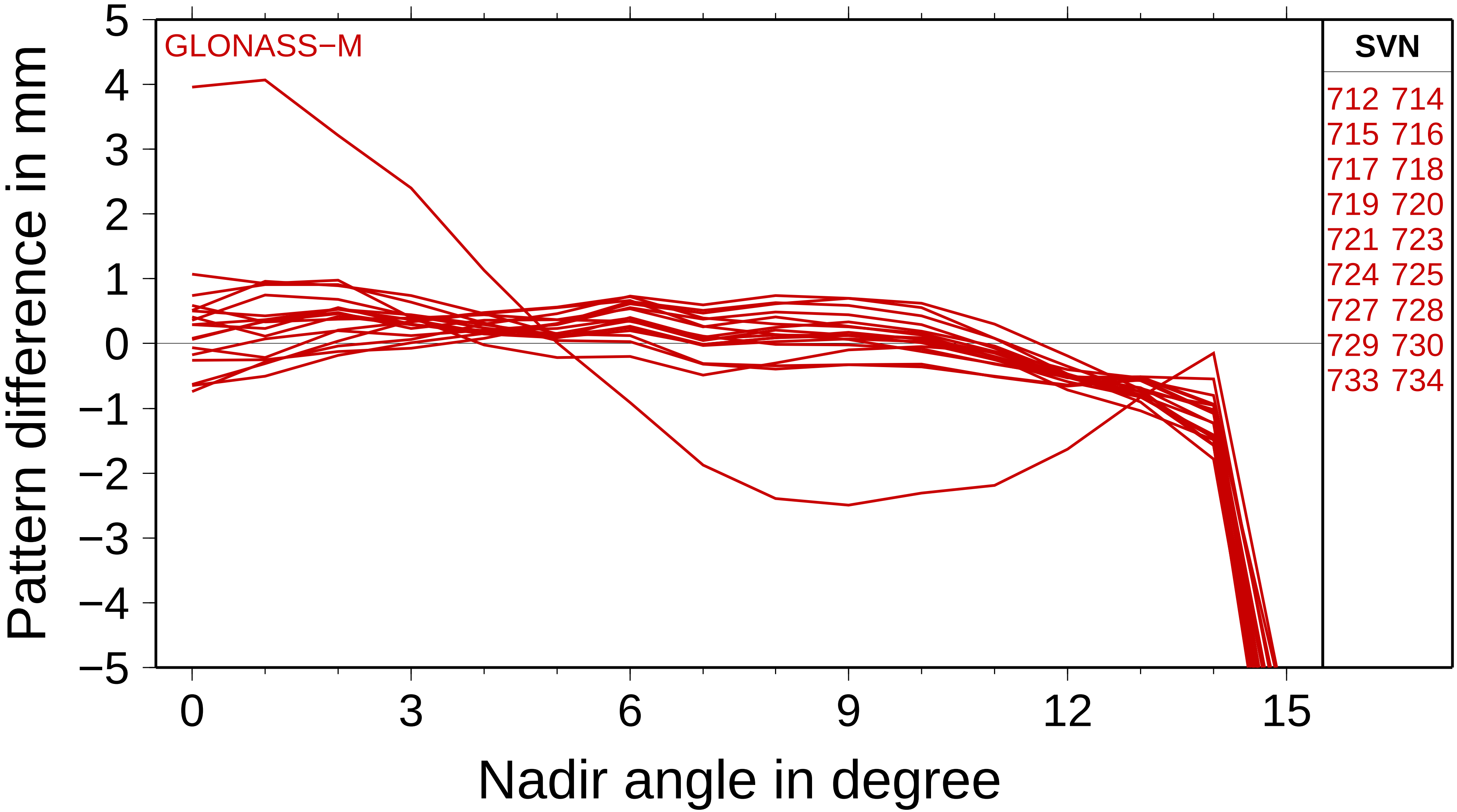

Satellite antenna phase center patterns, GLONASS

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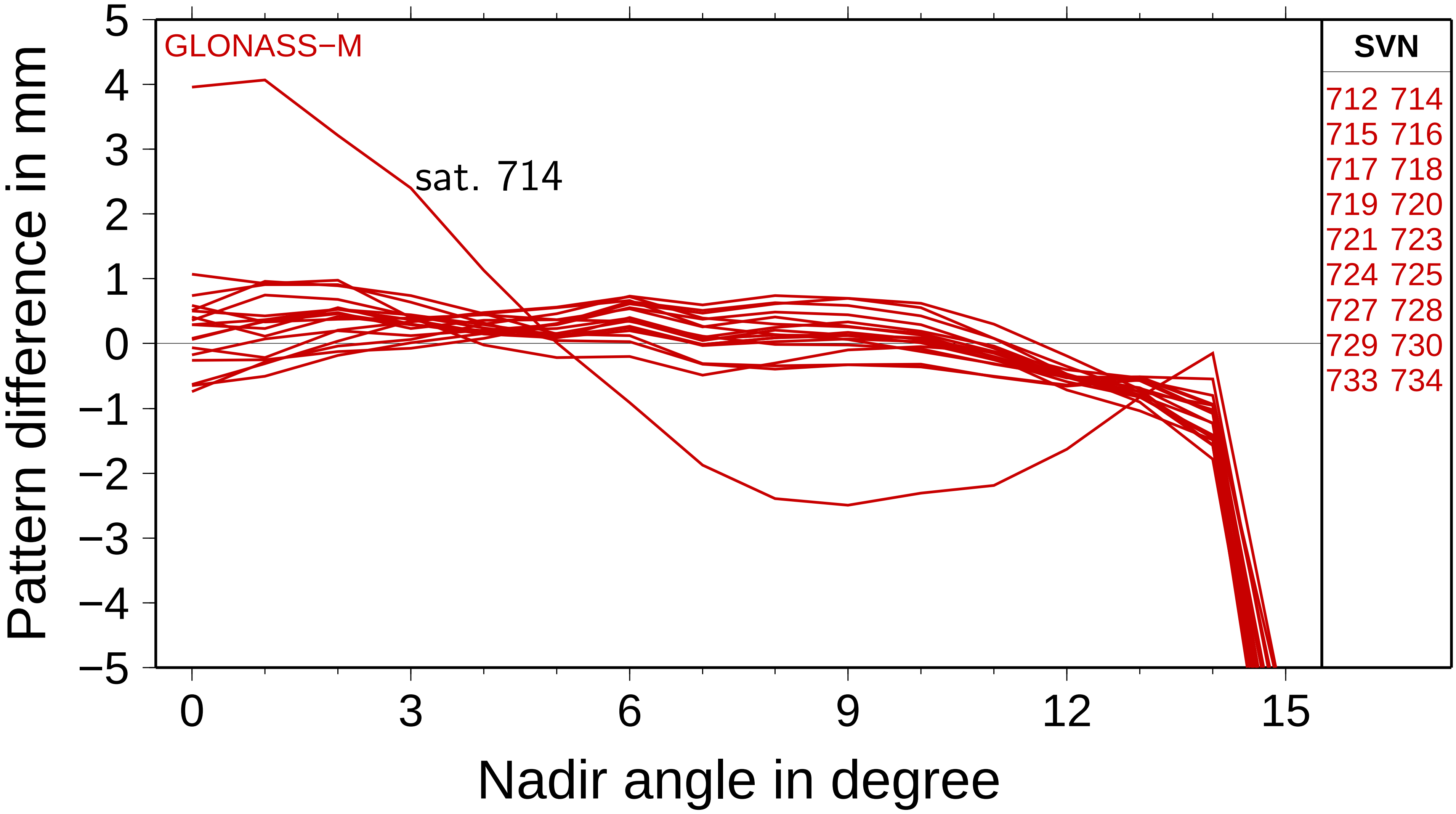
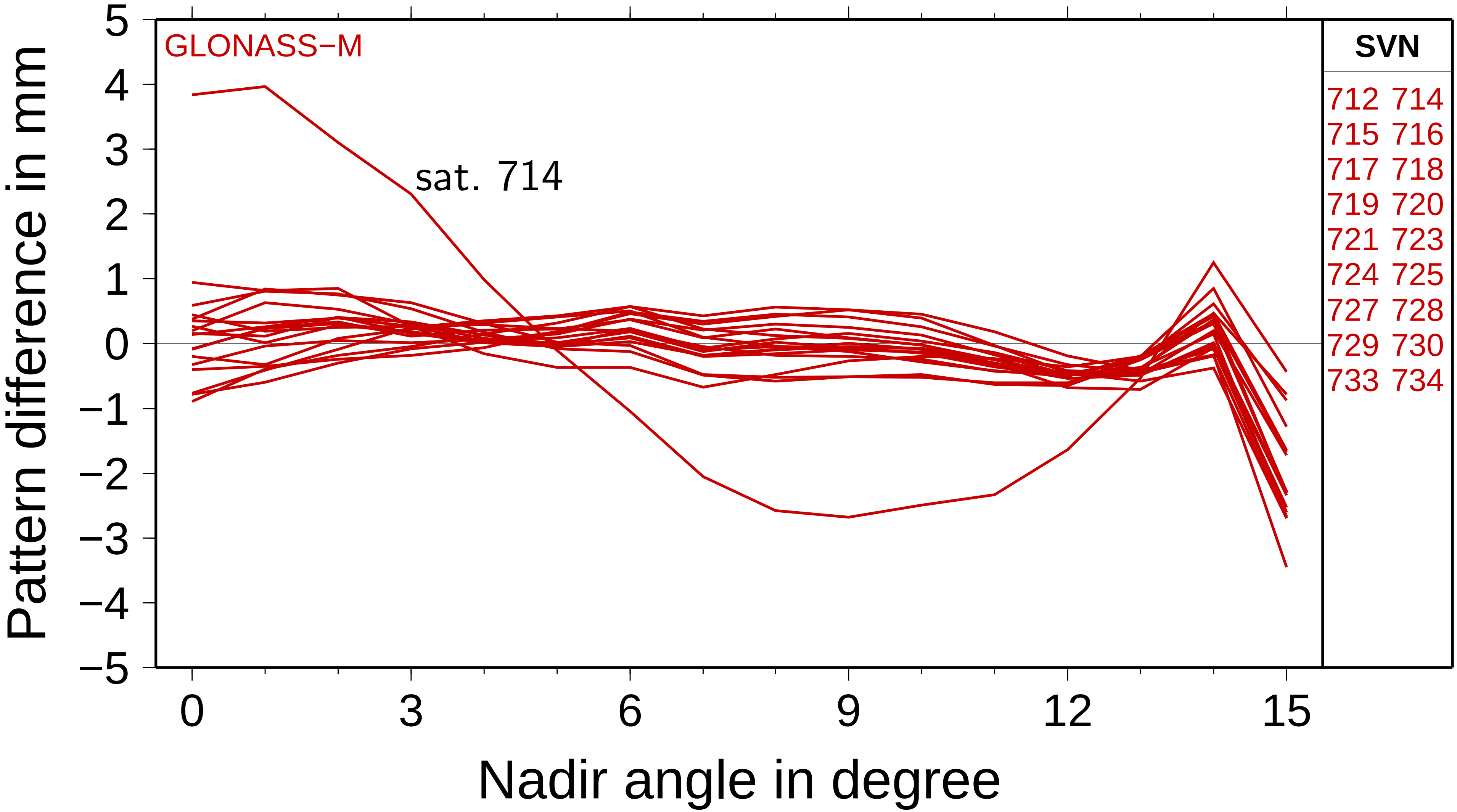


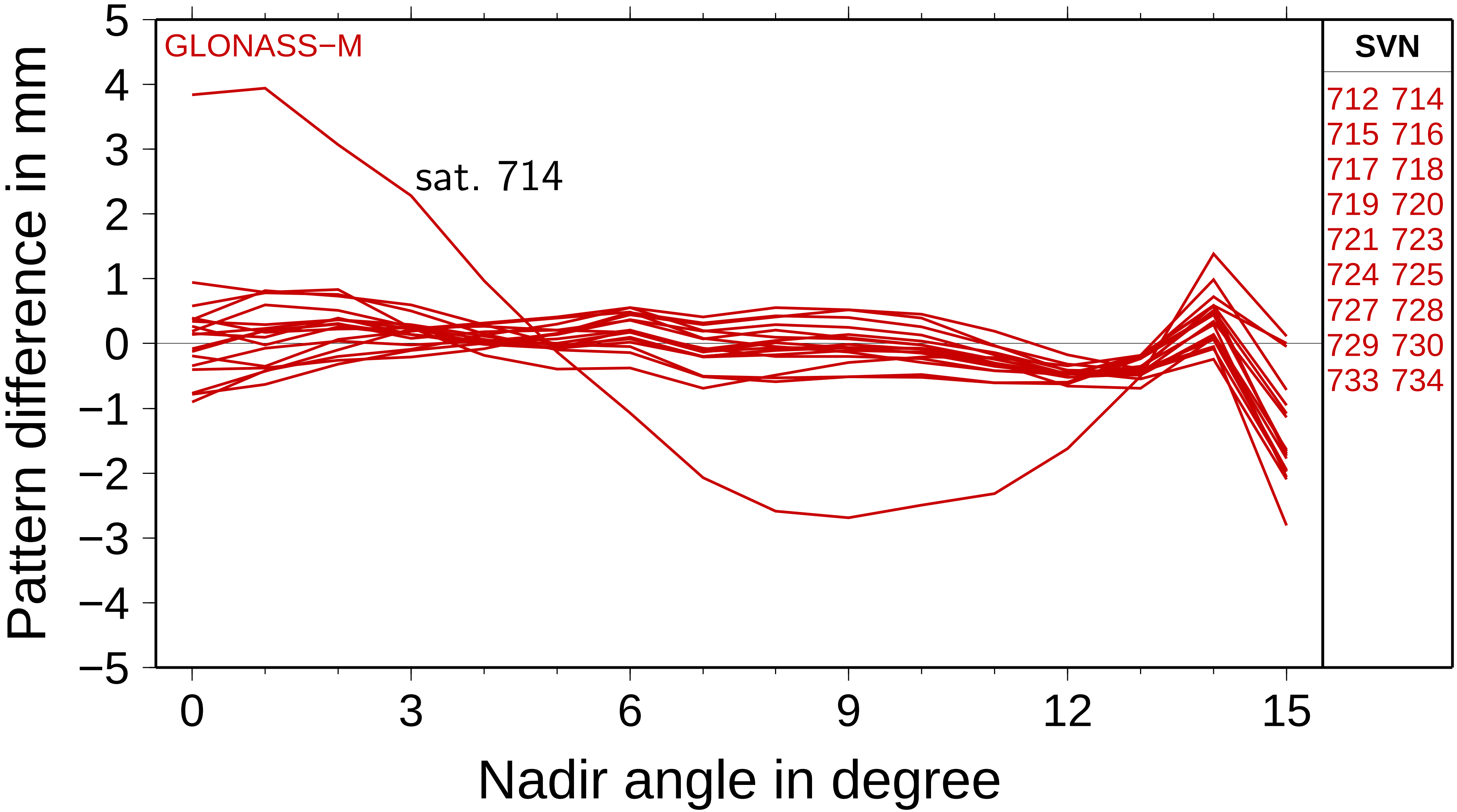
Satellite antenna phase center patterns, GLONASS

Differences between GMF–based estimates and `IGS08.ATX` values



Satellite antenna phase center patterns, GLONASS

Differences between VMF1–based estimates and IGS08.ATX values



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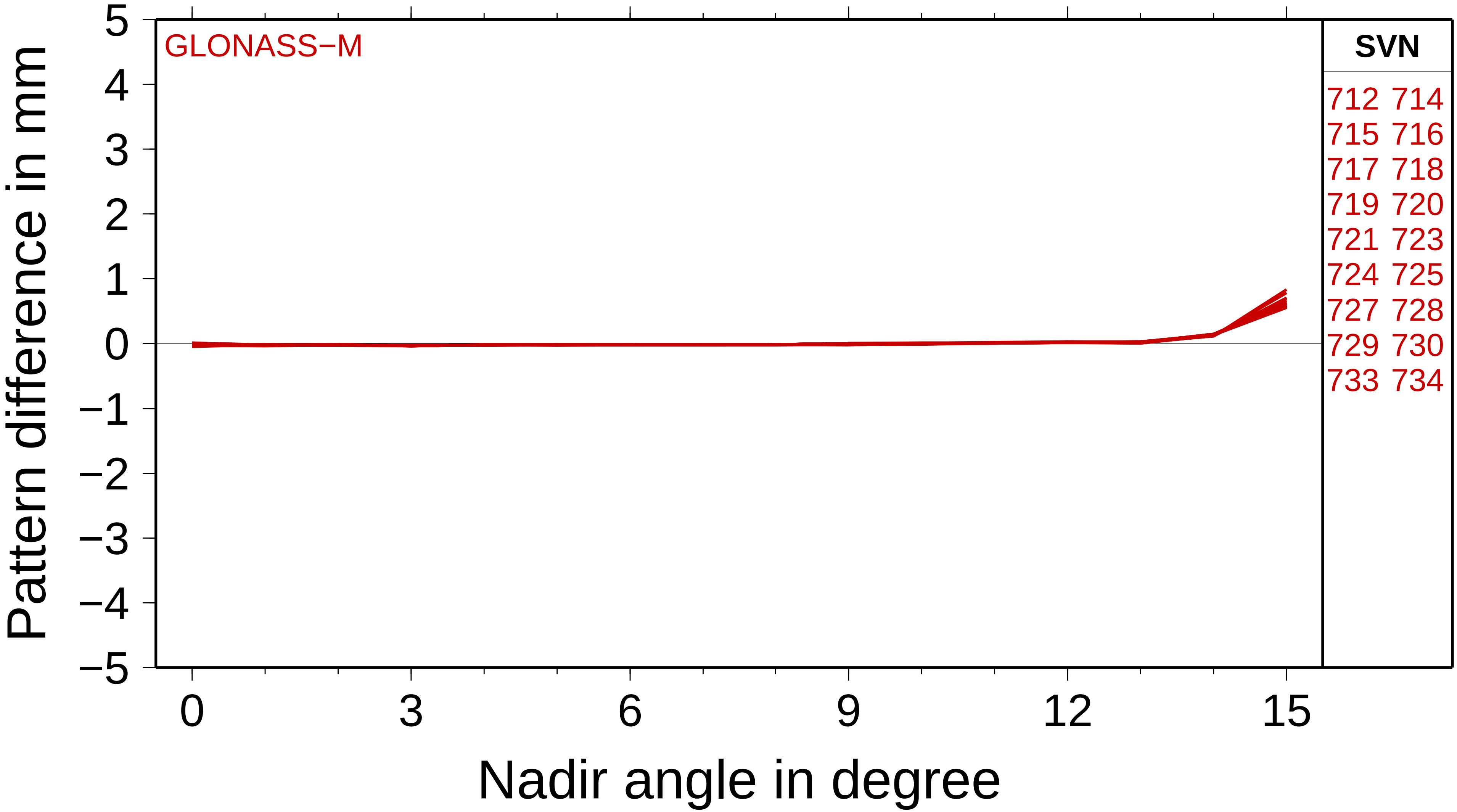

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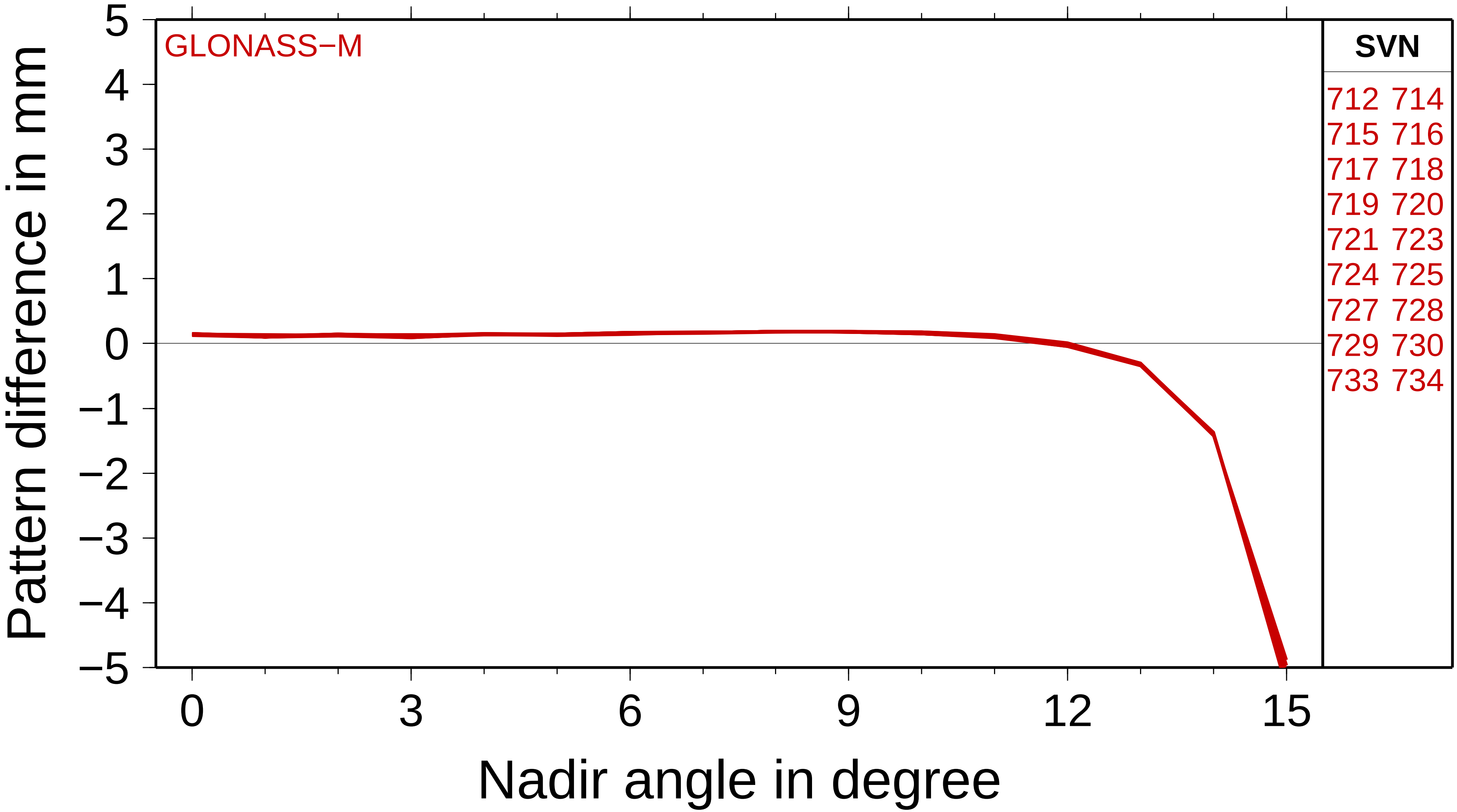
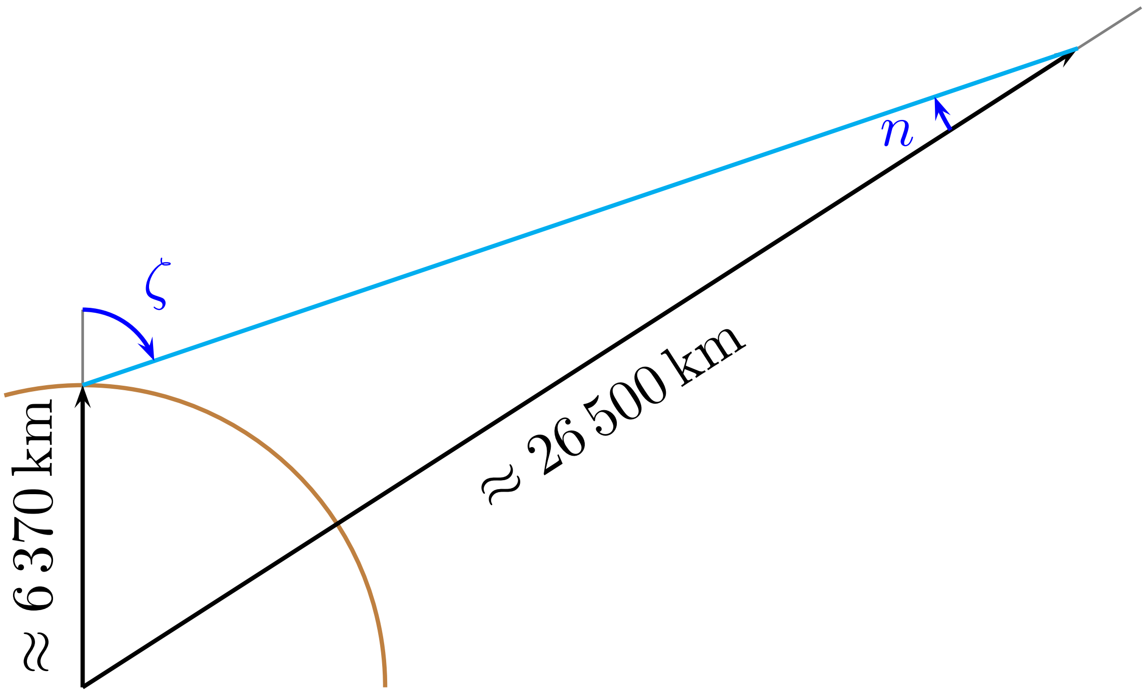


LEOs: Relation between elevation and nadir angles



n_{GPS}	ζ_{Earth}
0	0.0
2	8.4
4	16.9
6	25.8
8	35.4
10	46.2
12	59.9
13	69.4
14	
15	
16	

Values given in degree.

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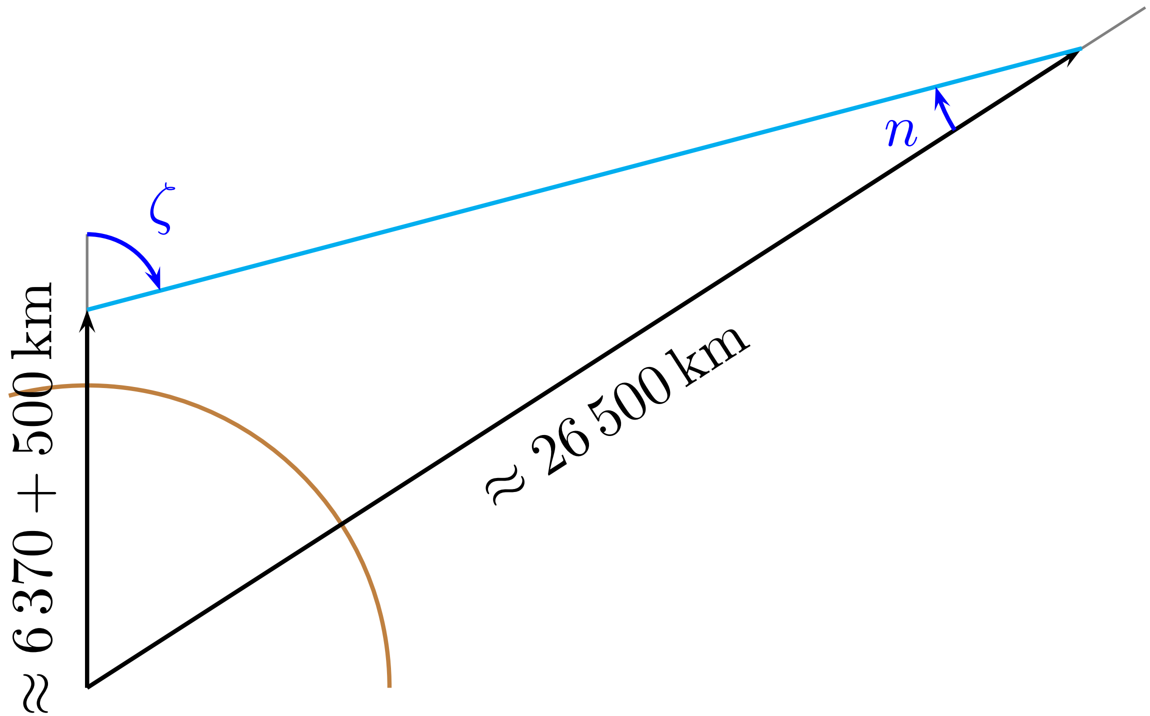

n_{GPS}	ζ_{Earth}	ζ_{GRACE}
0	0.0	0.0
2	8.4	7.7
4	16.9	15.6
6	25.8	23.8
8	35.4	32.5
10	46.2	42.0
12	59.9	53.3
13	69.4	60.2
14		68.9
15		86.7
16		

Values given in degree.

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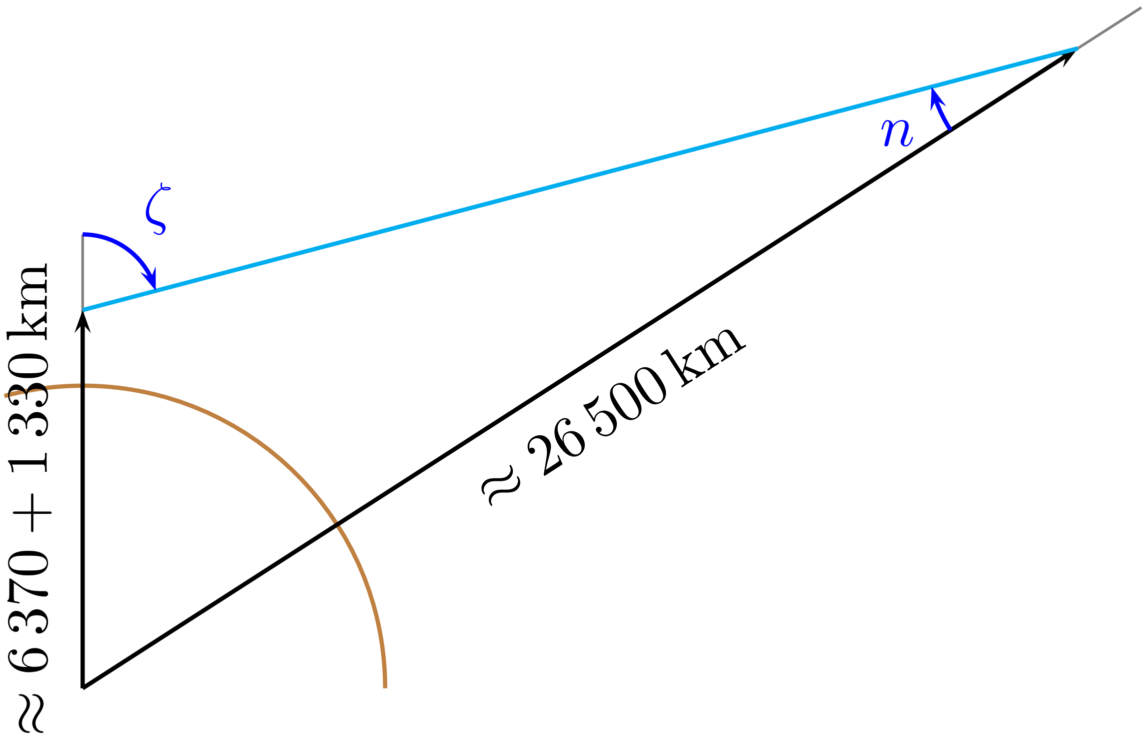

n_{GPS}	ζ_{Earth}	ζ_{GRACE}	ζ_{Jason2}
0	0.0	0.0	0.0
2	8.4	7.7	6.9
4	16.9	15.6	13.9
6	25.8	23.8	21.1
8	35.4	32.5	28.6
10	46.2	42.0	36.7
12	59.9	53.3	45.7
13	69.4	60.2	50.7
14		68.9	56.4
15		86.7	63.0
16			71.6

Values given in degree.

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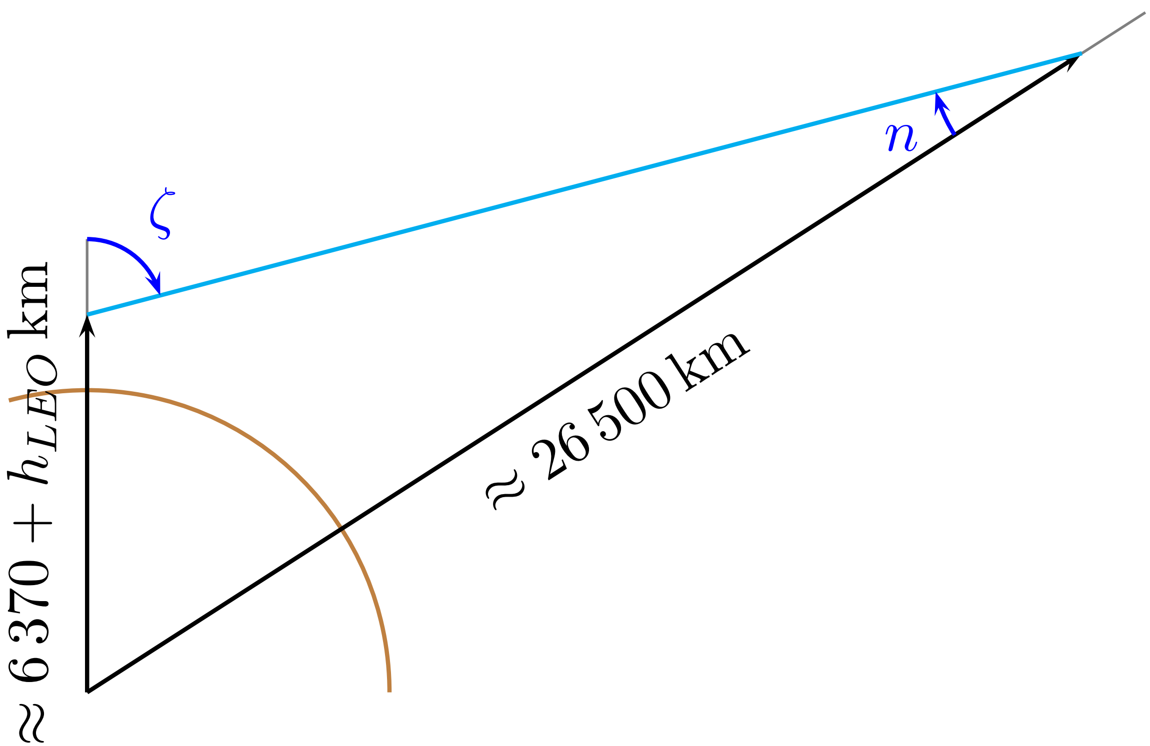

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13	69.4	60.2	50.7
14		68.9	56.4
15		86.7	63.0
16			71.6
13.8	85		
15.0		85	
16.8			85

Values given in degree.

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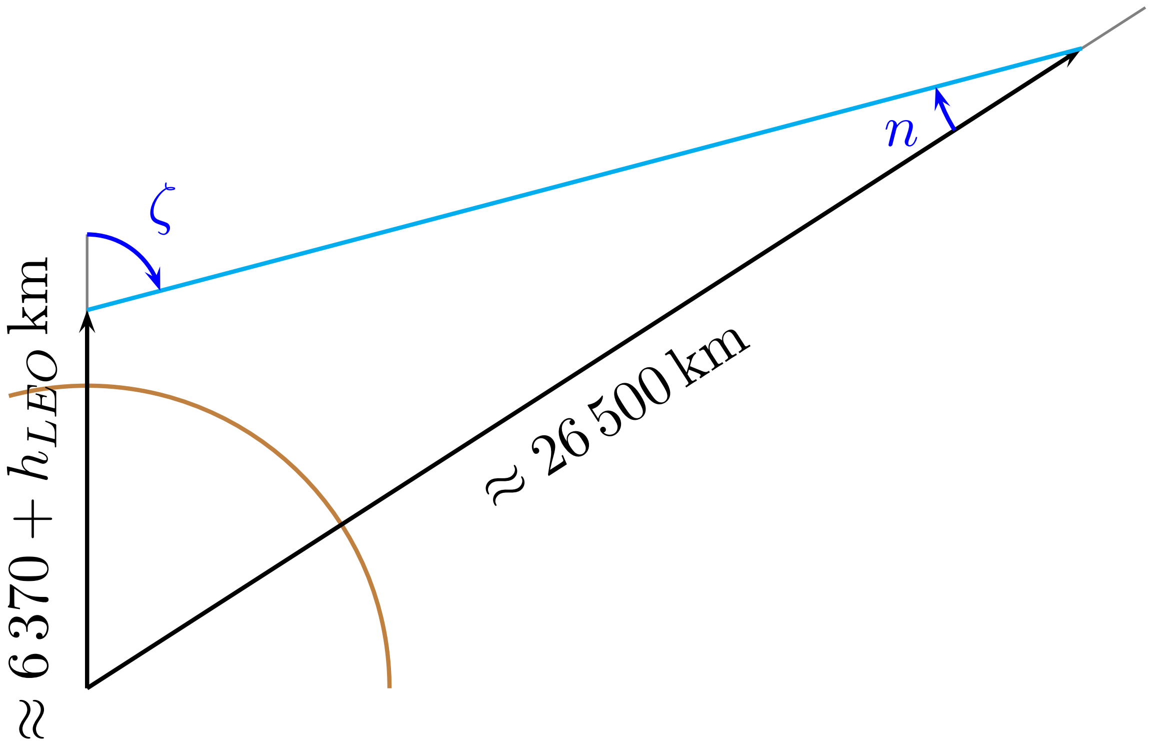

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12	59.9	53.3	45.7
13	69.4	60.2	50.7
14		68.9	56.4
15		86.7	63.0
16			71.6
13.9	90		
15.0		90	
16.9			90

Values given in degree.

Use of LEOs for GNSS satellite antenna estimation

Advantages:

- due to the higher altitude bigger nadir angles may be achieved

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- small number of missions with a limited number of antenna types
- near–field environment of the antenna onboard the LEO
- only available for GPS until now

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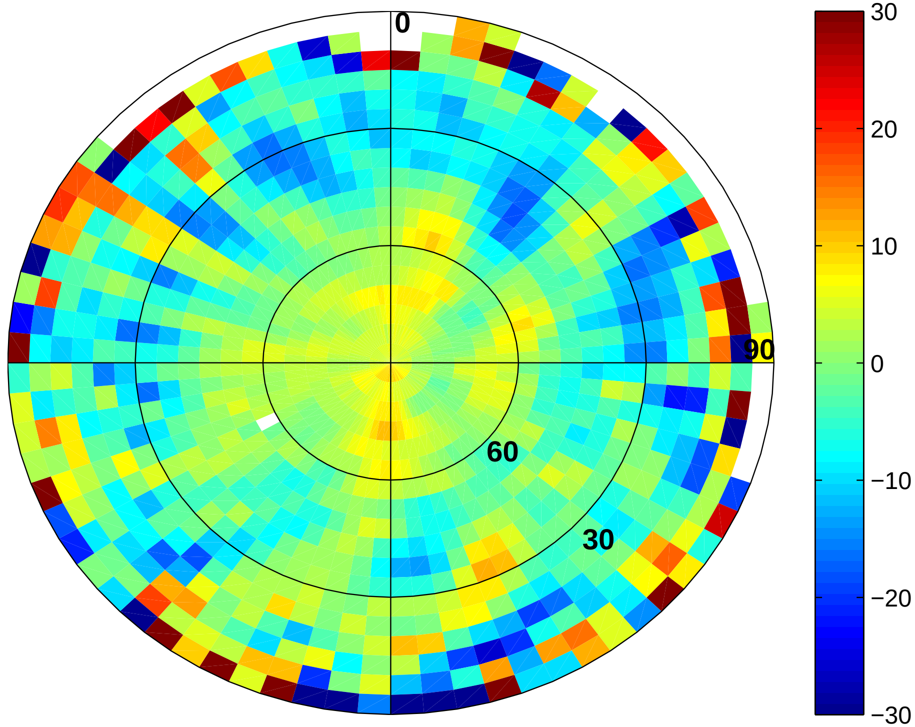
Use of LEOs for GNSS satellite antenna estimation

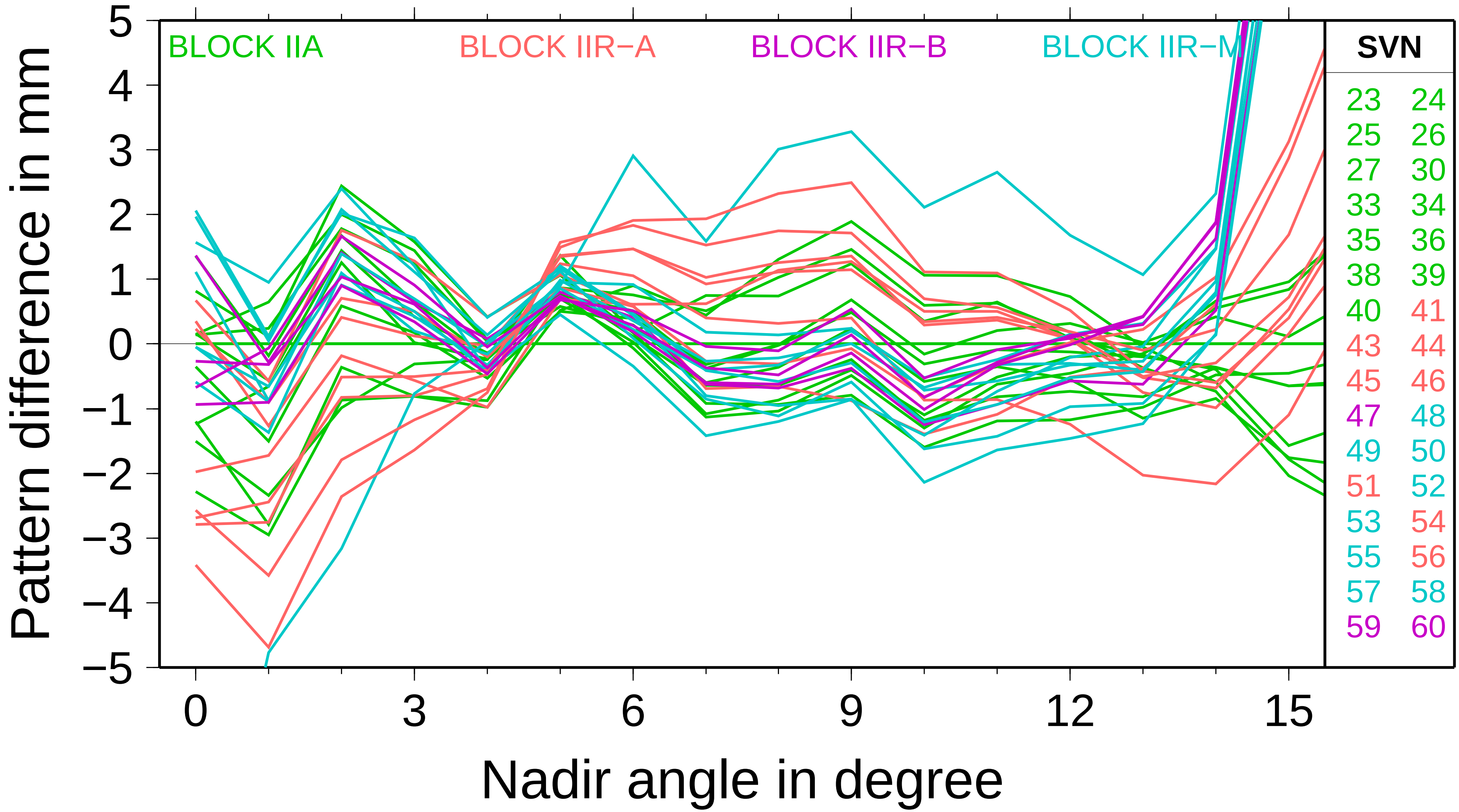
- To compensate the near–field environment antenna phase center maps need to be co–estimated for the LEO–POD.
- These maps are fully correlated with the GPS satellite antenna phase center patterns.
- A combination of several missions is preferable to solve for the GPS satellite antenna phase center patterns.

Antenna phase center map for Jason–2



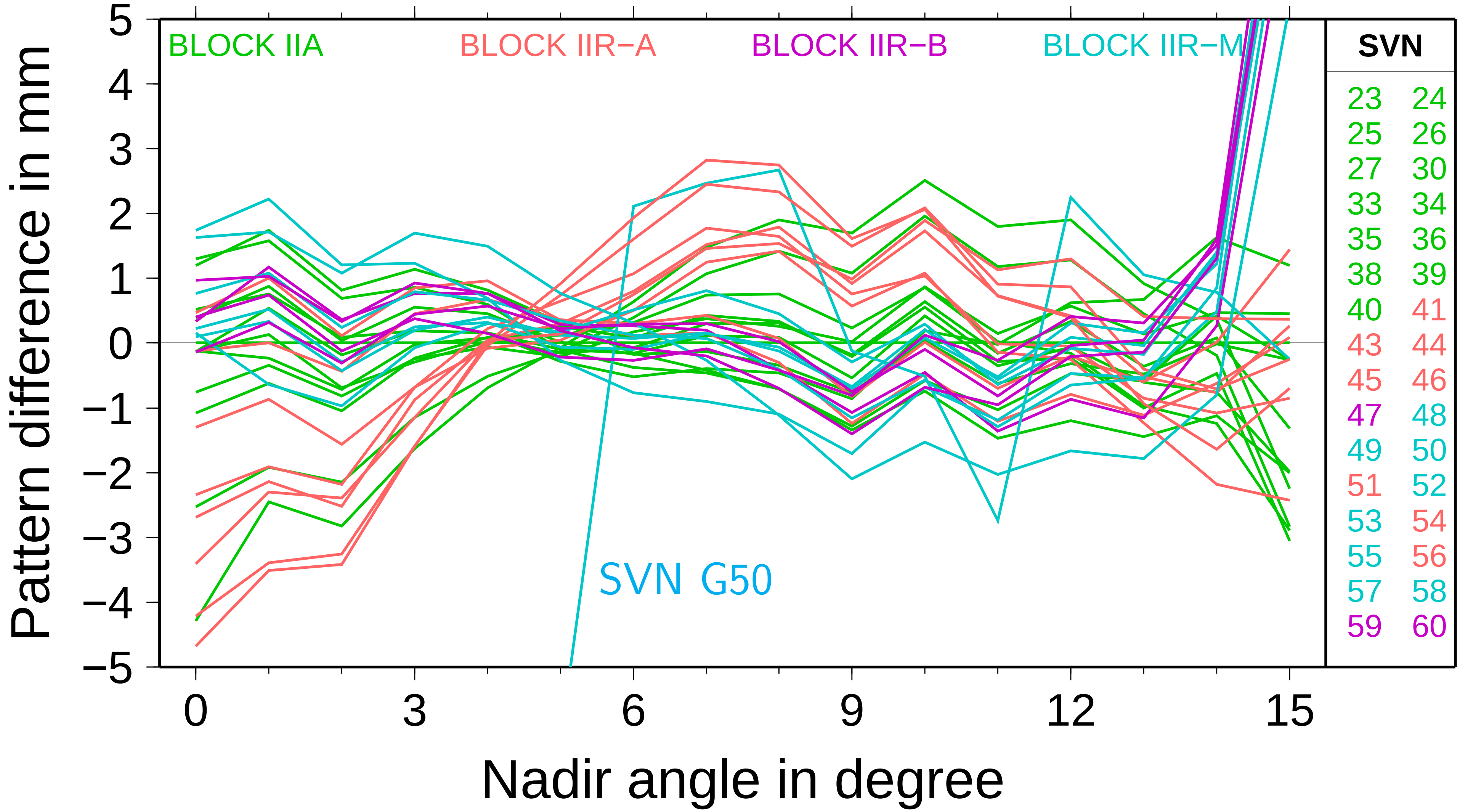
GPS satellite antenna phase center patterns

Differences between Jason–2–based estimates and IGS08.ATX values



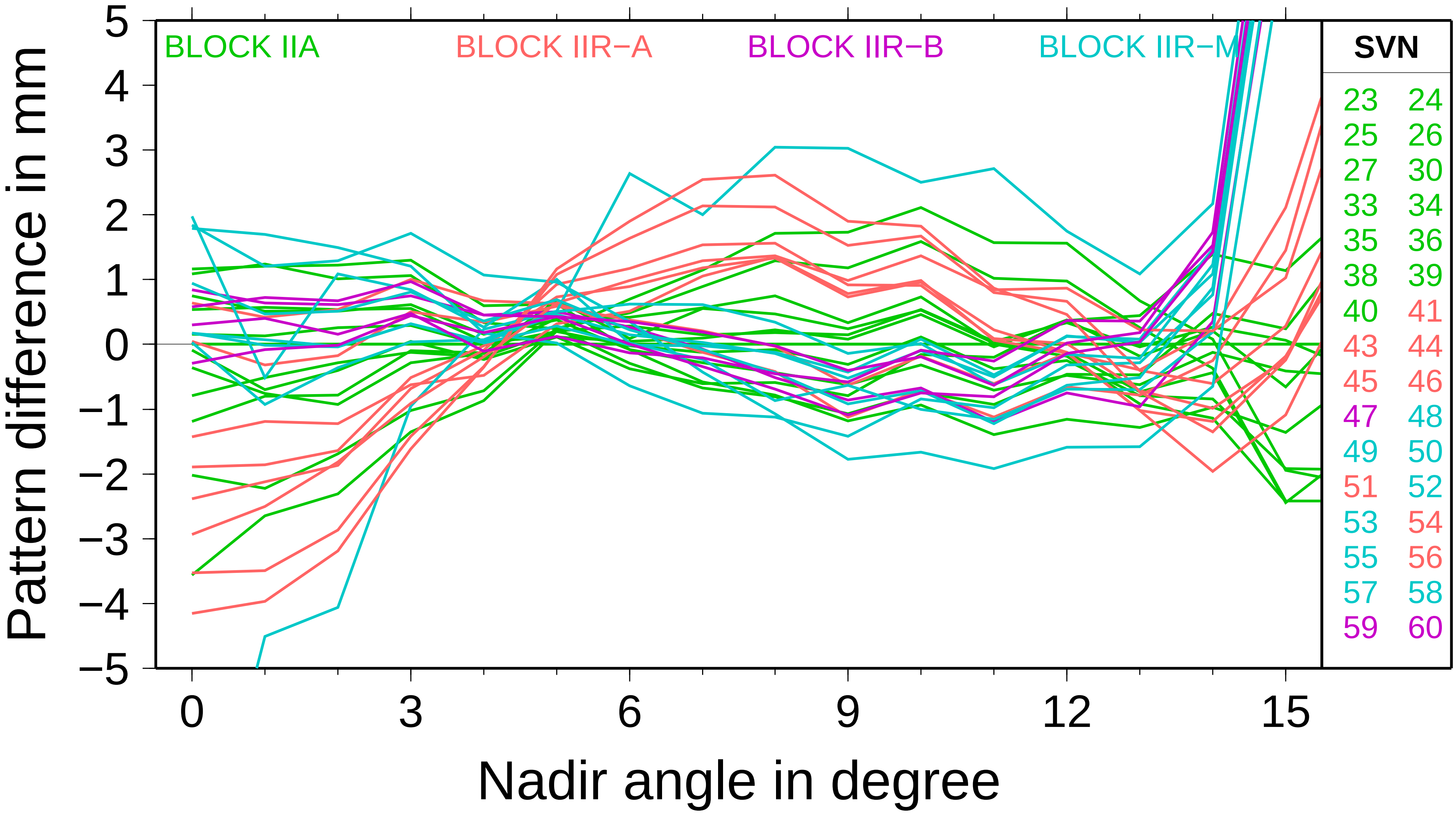
GPS satellite antenna phase center patterns

Differences between GRACE A/B–based estimates and `IGS08.ATX` values



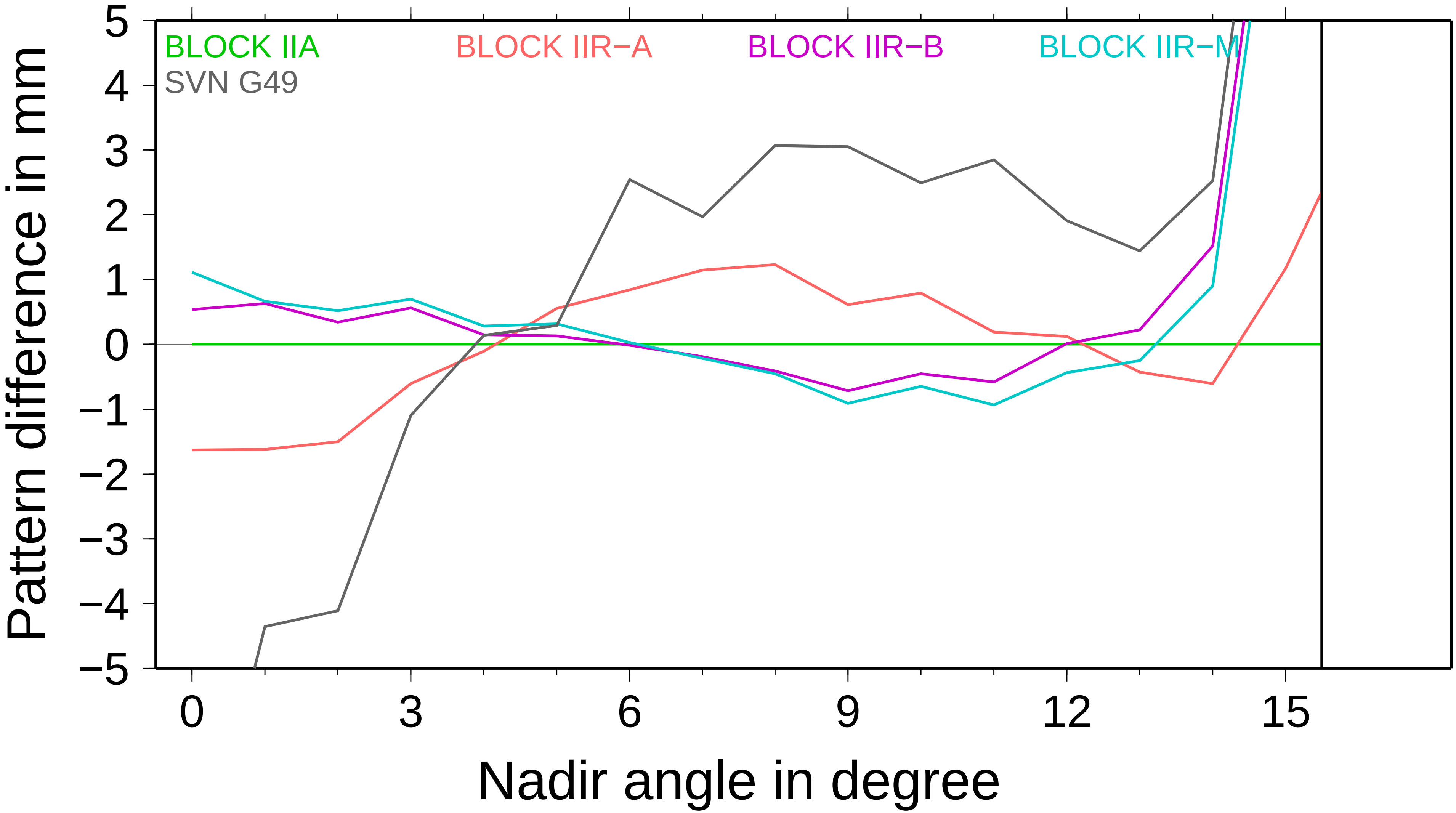
GPS satellite antenna phase center patterns

Differences between Jason+GRACE–based estimates and IGS08.ATX values



GPS satellite antenna phase center patterns

Differences between Jason+GRACE–based estimates and `IGS08.ATX` values



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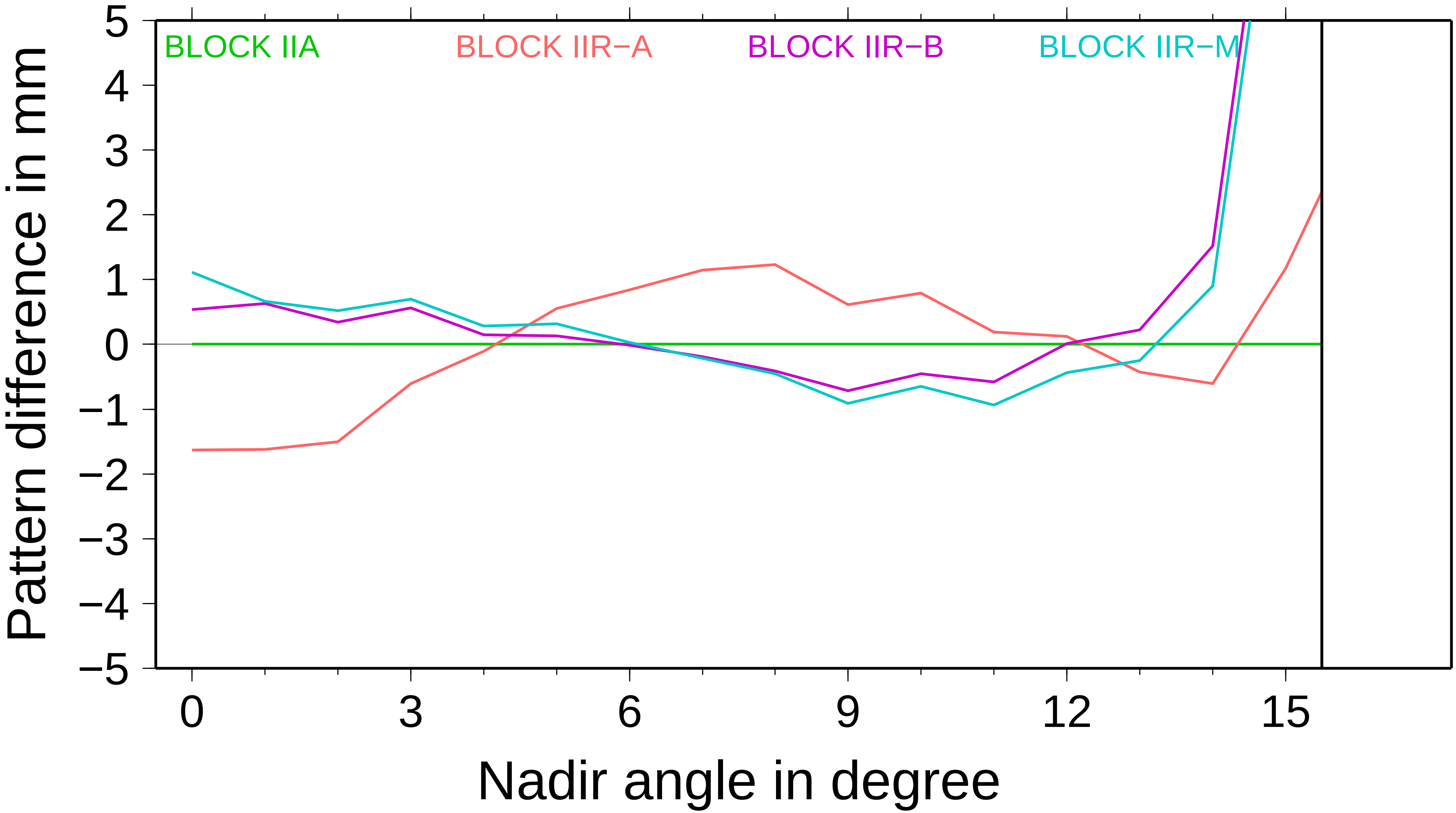
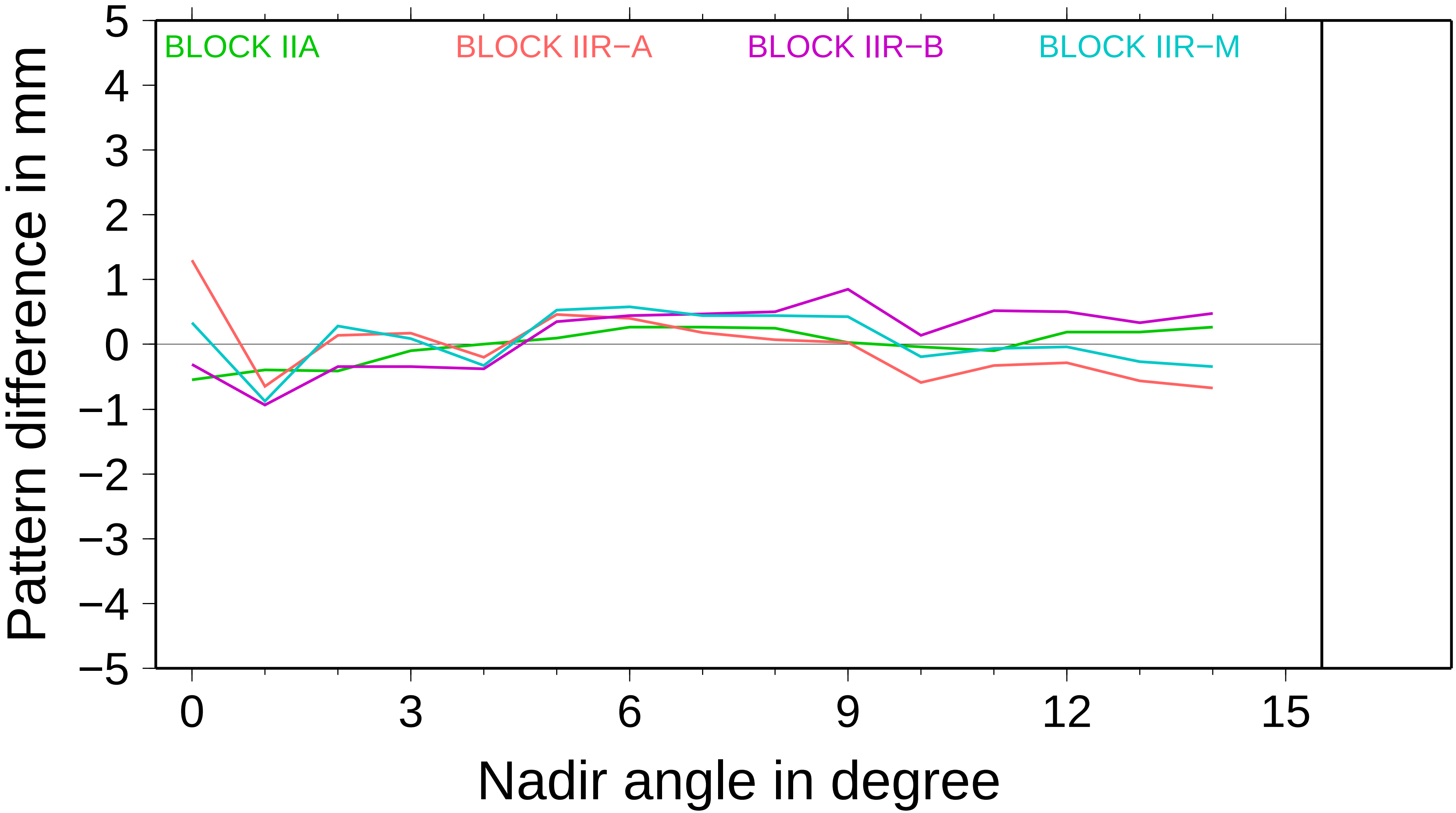


GPS satellite antenna phase center patterns

Differences between Jason–2– and GMF–based estimates



GPS satellite antenna phase center patterns

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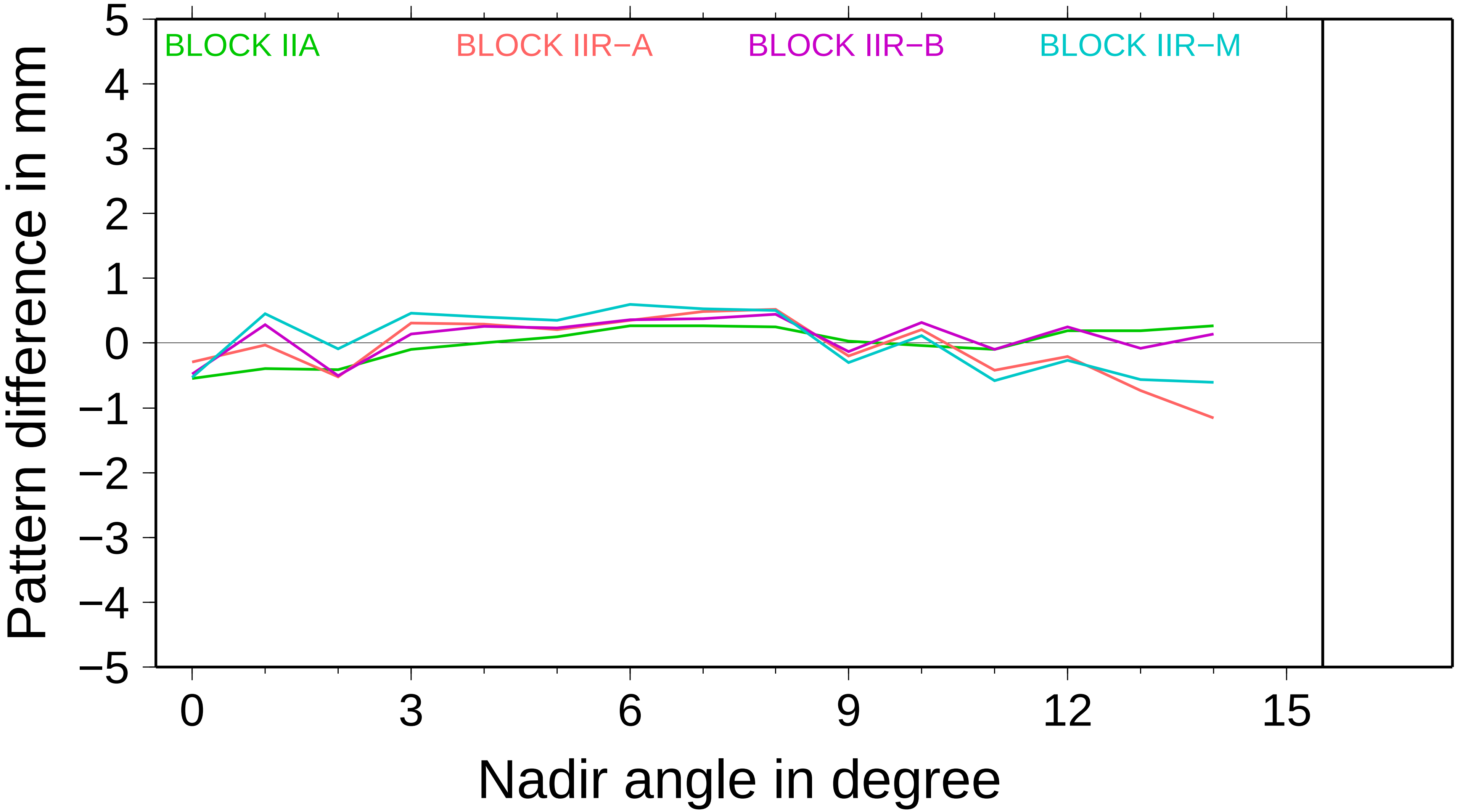
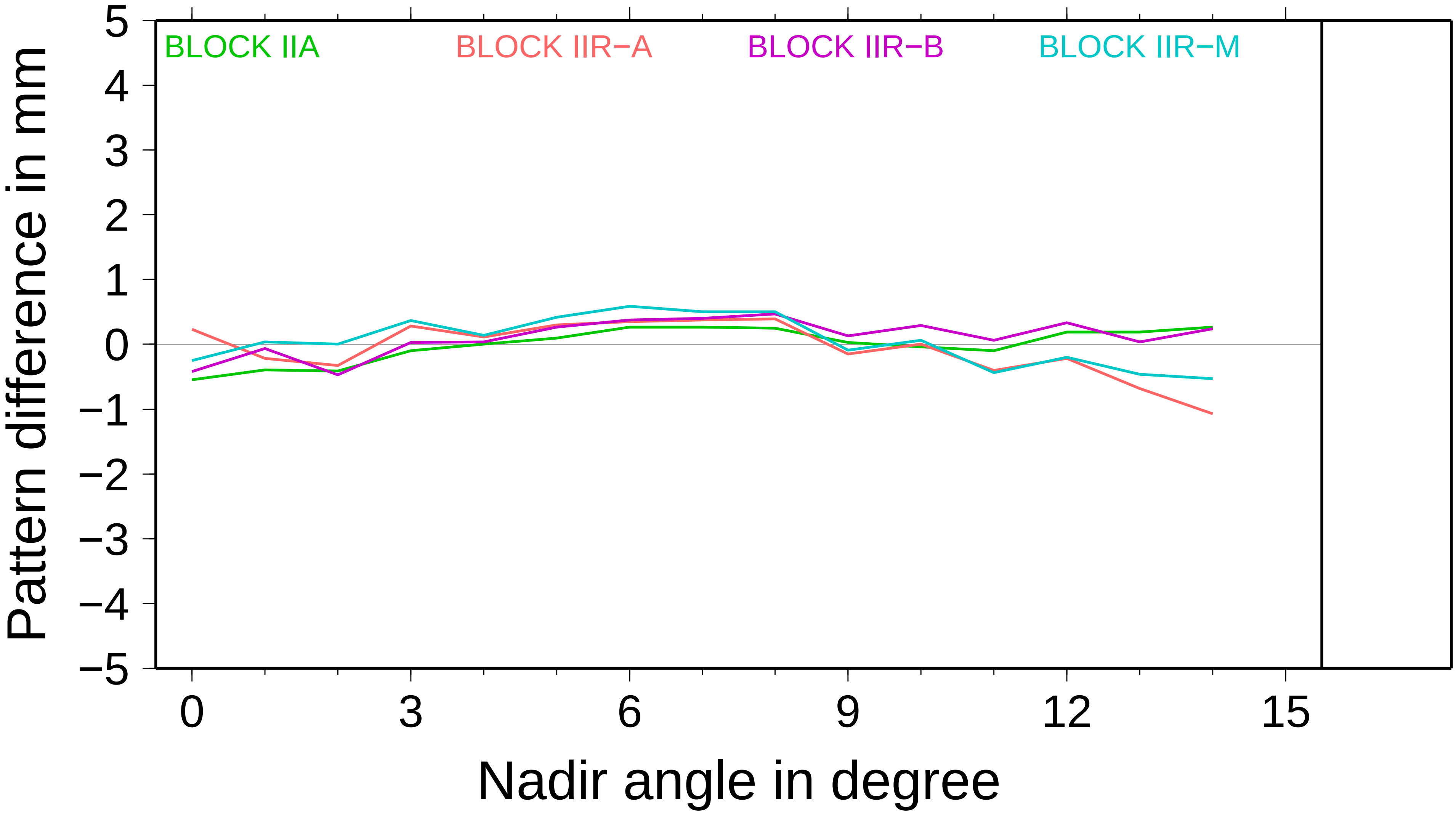


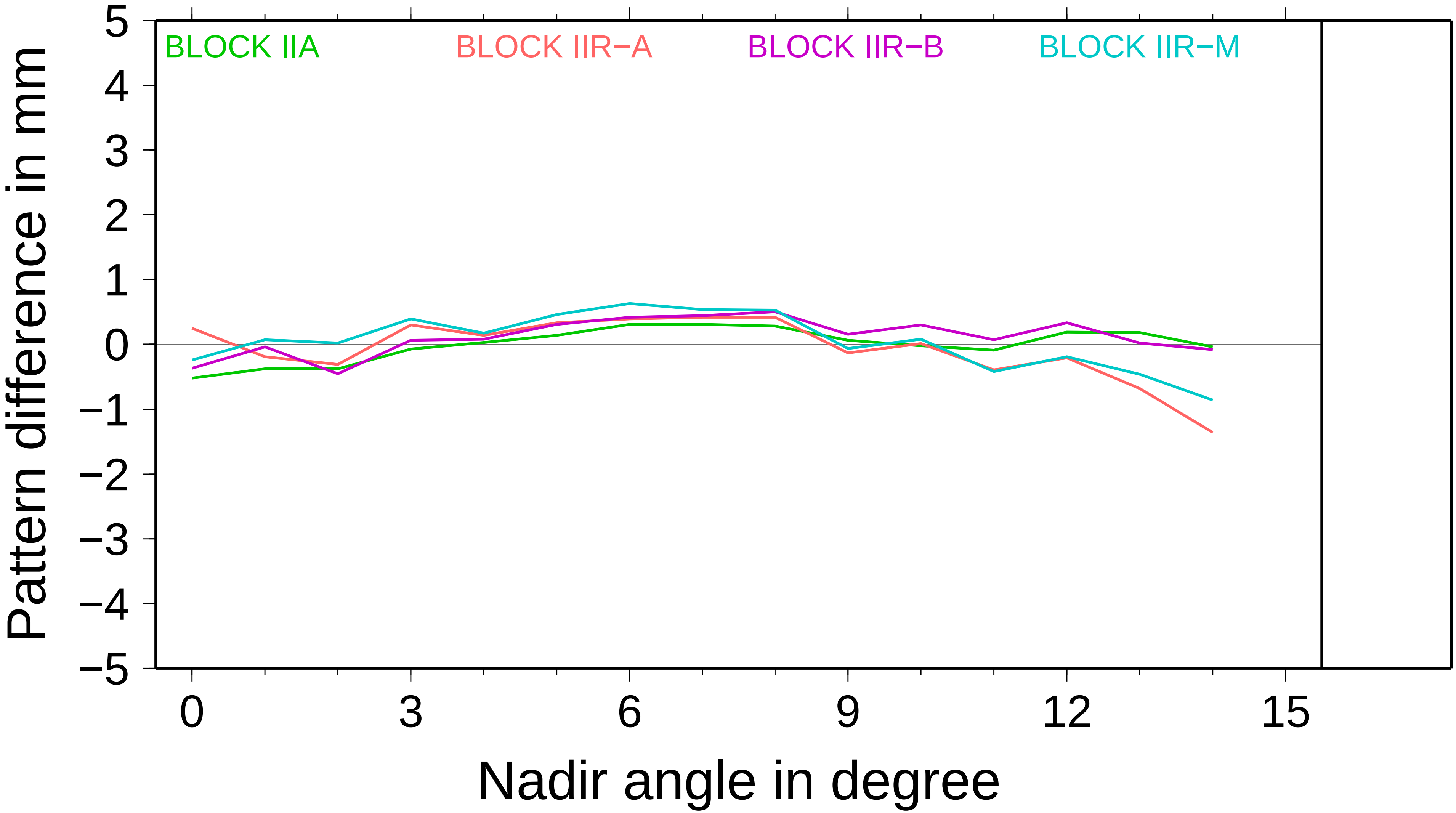
GPS satellite antenna phase center patterns

Differences between Jason+GRACE– and GMF–based estimates



GPS satellite antenna phase center patterns

Differences between Jason+GRACE– and VMF1–based estimates



GPS satellite antenna phase center patterns

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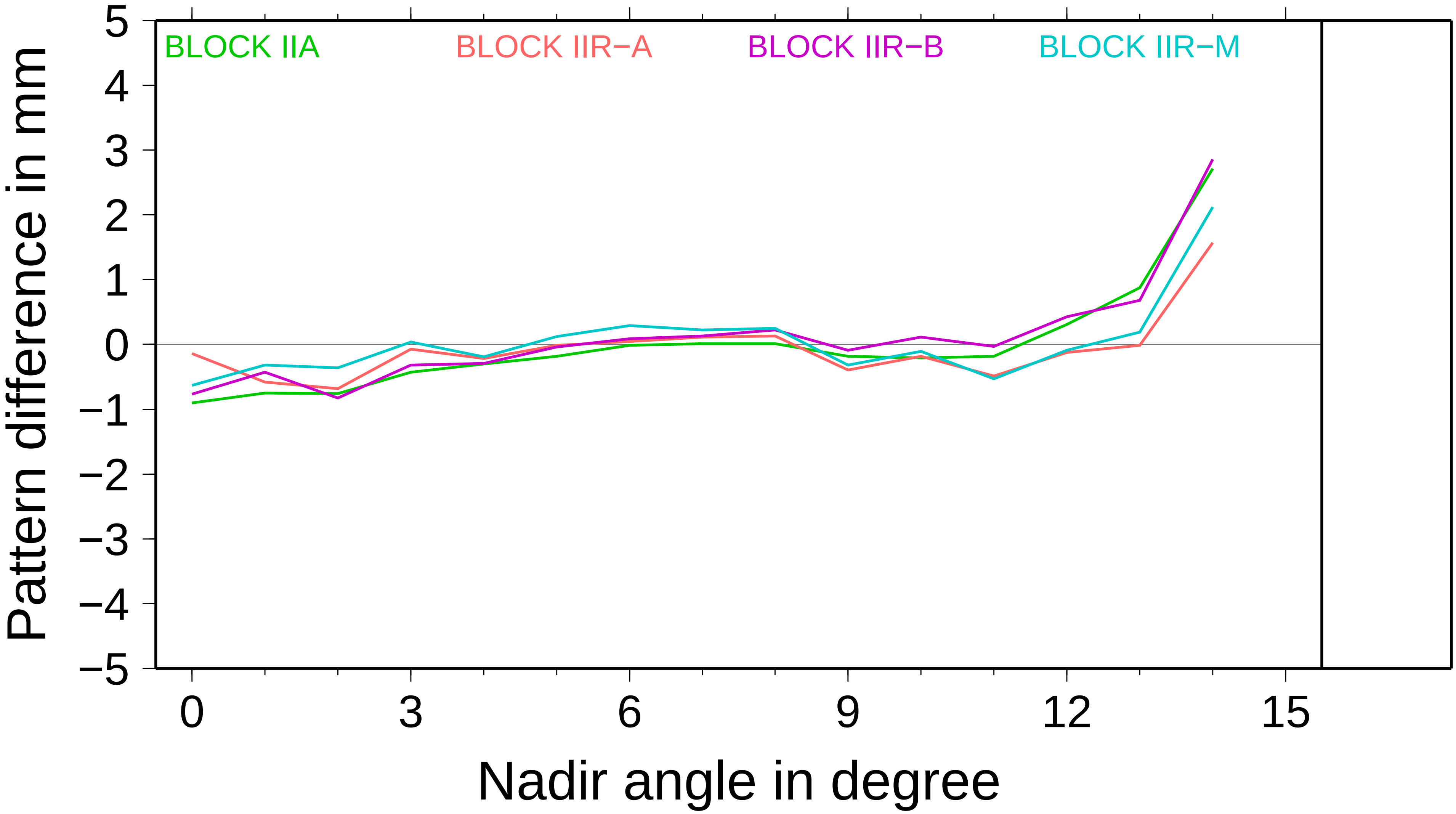

GPS satellite antenna phase center patterns

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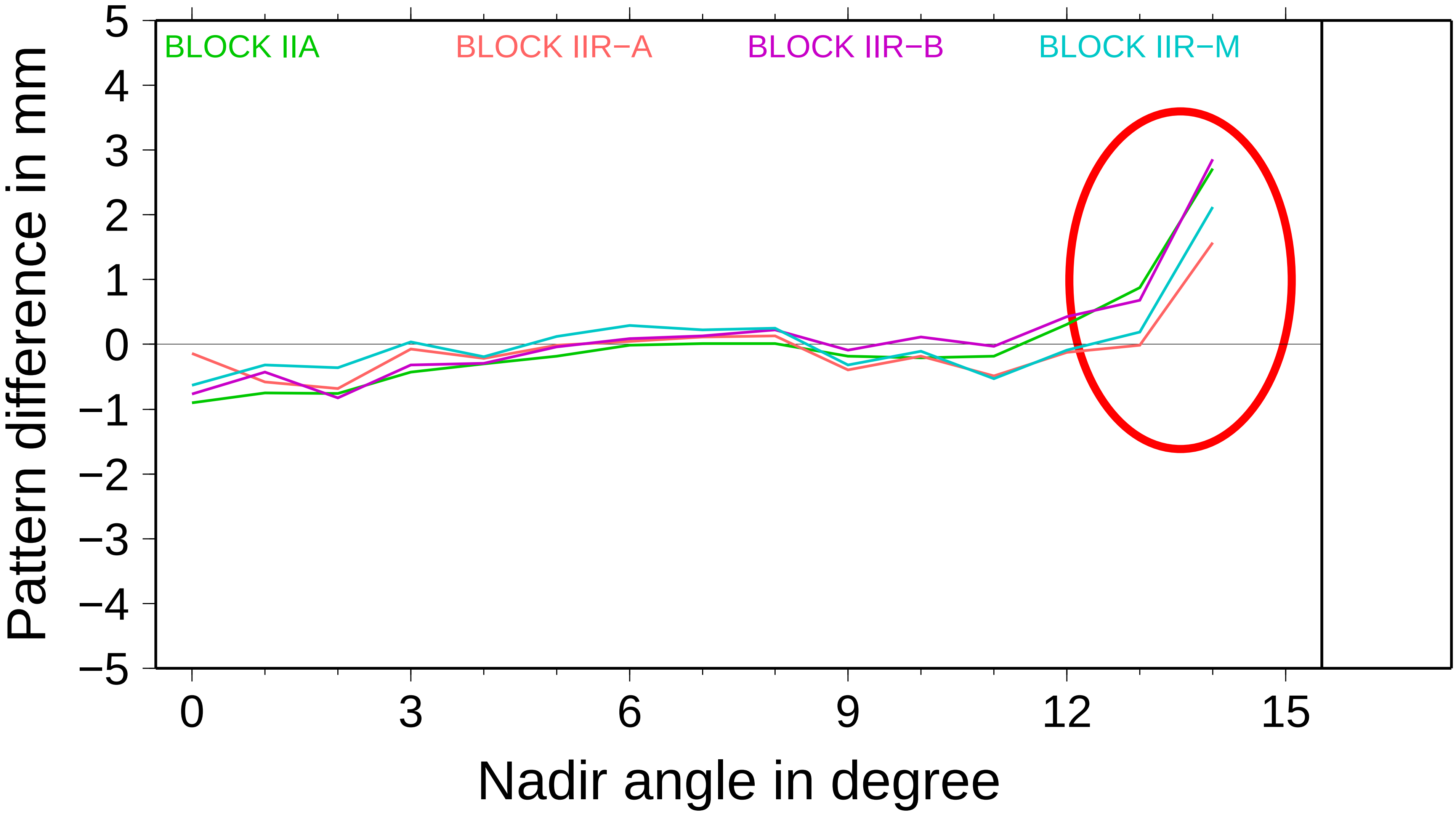
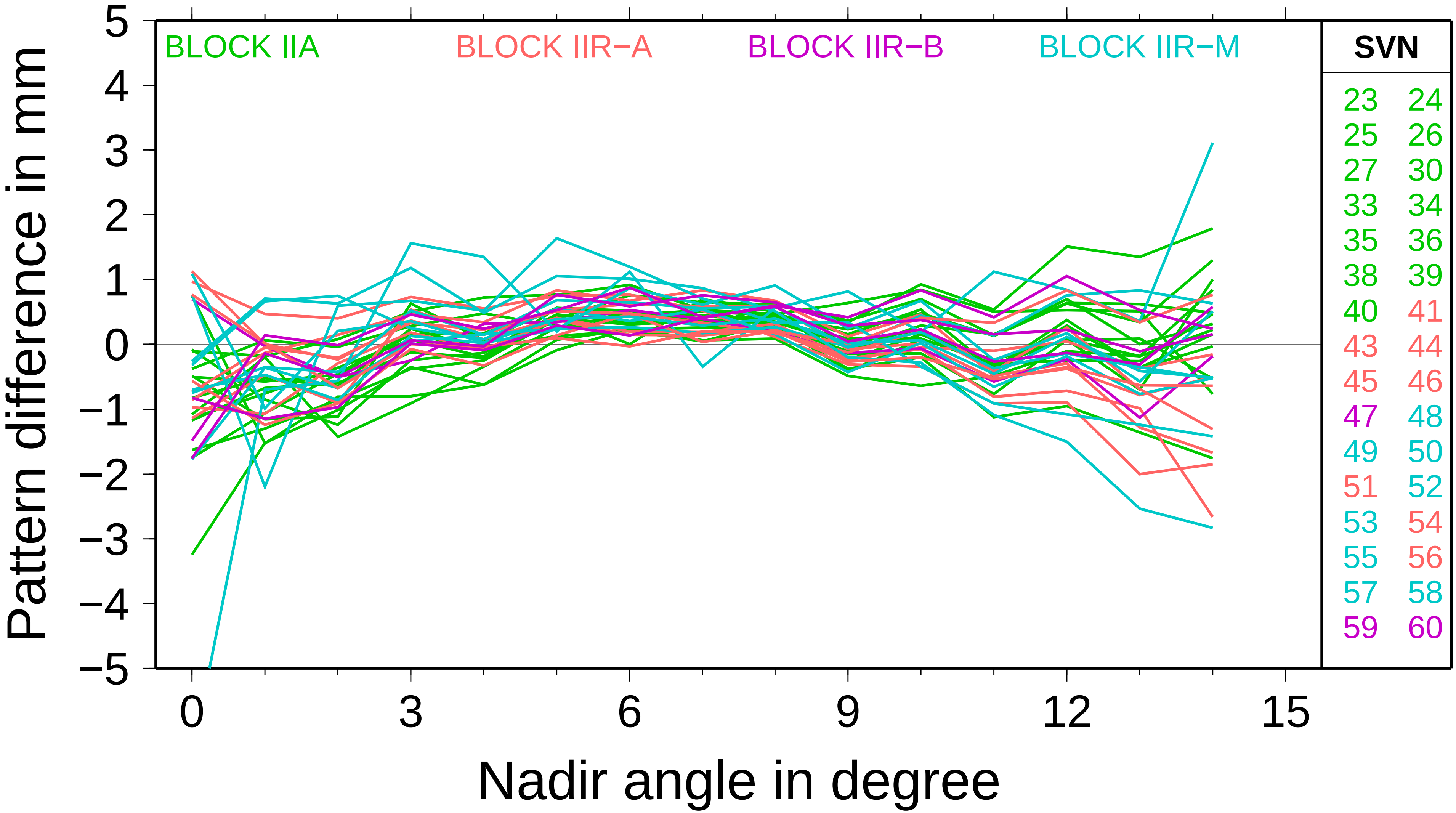


GPS satellite antenna phase center patterns

Differences between Jason+GRACE–based and GMF–based estimates



GPS satellite antenna phase center patterns

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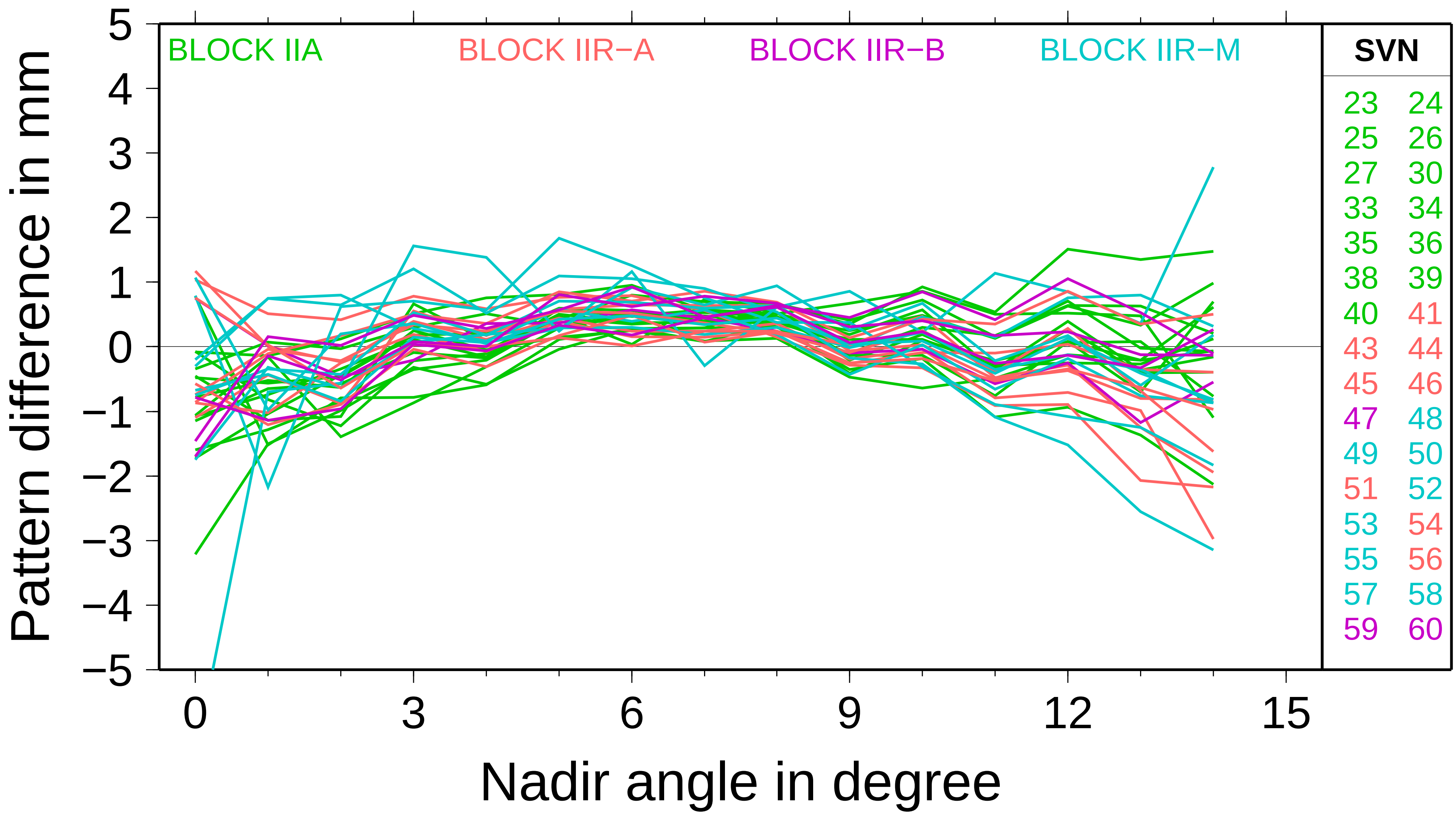

GPS satellite antenna phase center patterns

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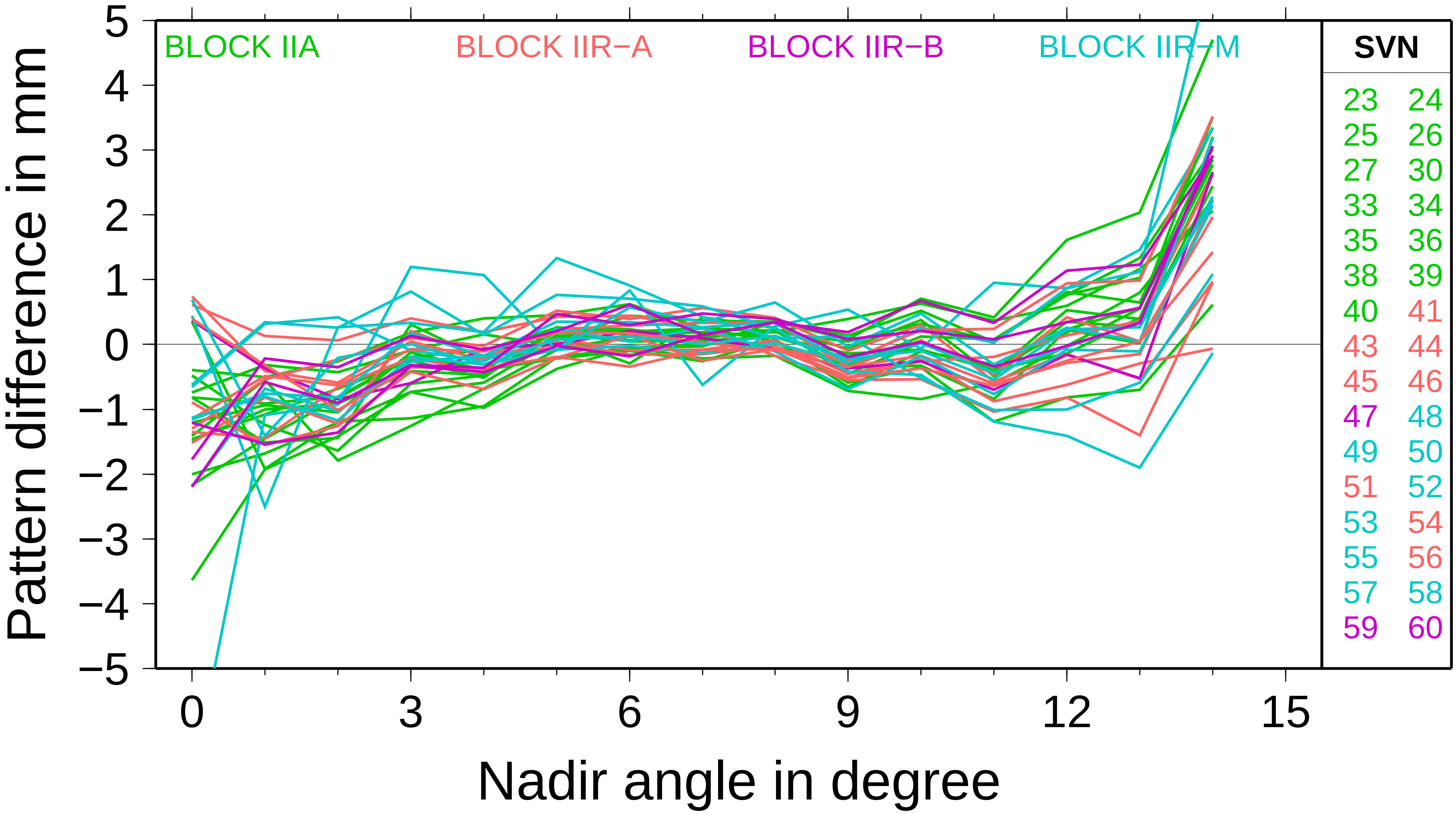

Influence on the station coordinates

- Four sets of satellite antenna phase center patterns are available:
  - from the VMF1–based cumulative solution
  - from the GMF–based cumulative solution
  - from the NMF–based cumulative solution
  - from the Jason/GRACE–based solution

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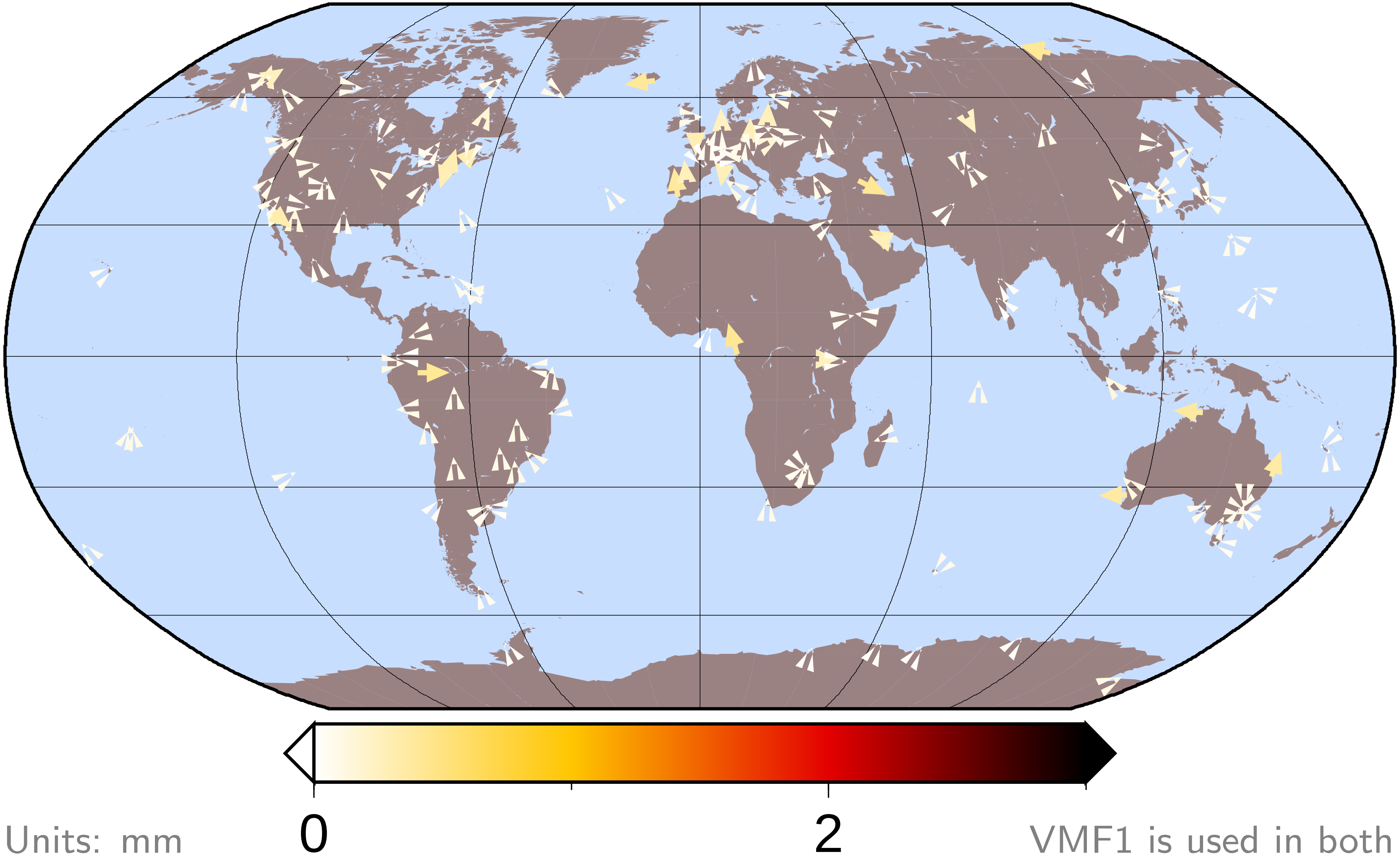
- *How do the different sets of satellite antenna phase center patterns influence the coordinate solution?*

Position differences between the solutions using *satellite*–specific GMF– and VMF1–based satellite antenna pattern

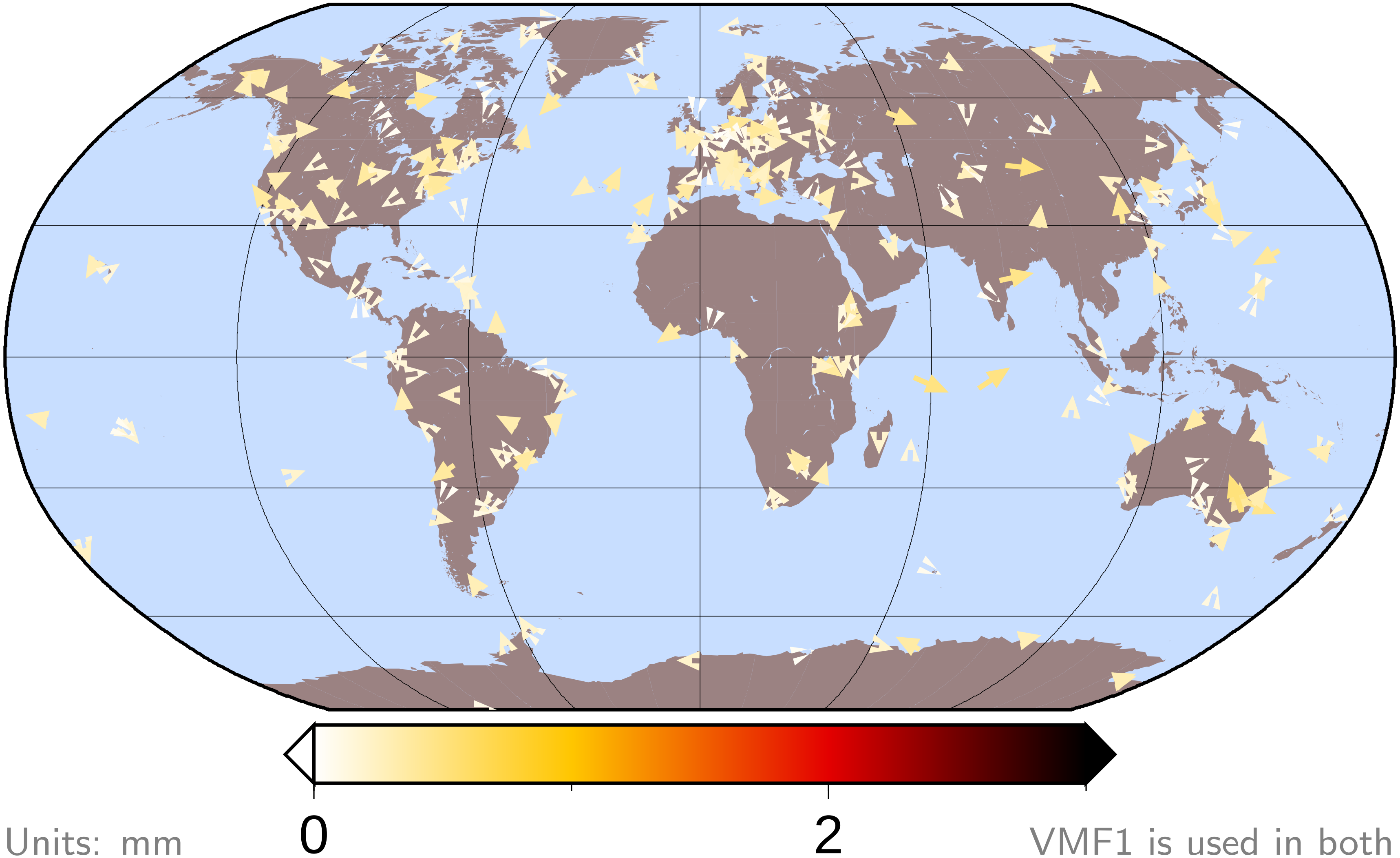


Units: mm

VMF1 is used in both solutions

Influence on the station positions

Position differences between the solutions using *satellite*–specific NMF– and VMF1–based satellite antenna pattern

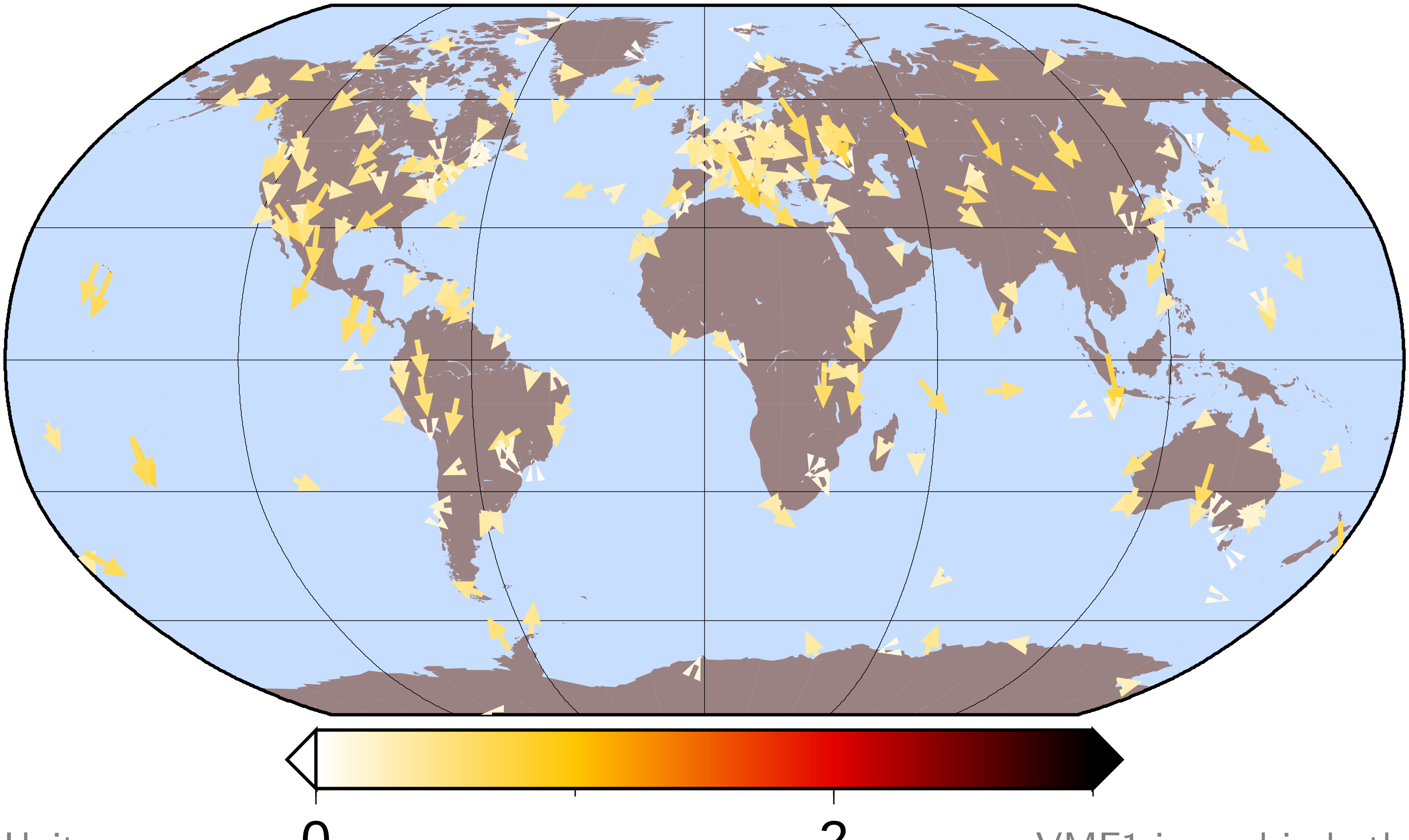


Units: mm

VMF1 is used in both solutions

Influence on the station positions

Position differences between the solutions using *satellite*–specific Jason+GRACE– and VMF1–based satellite antenna pattern

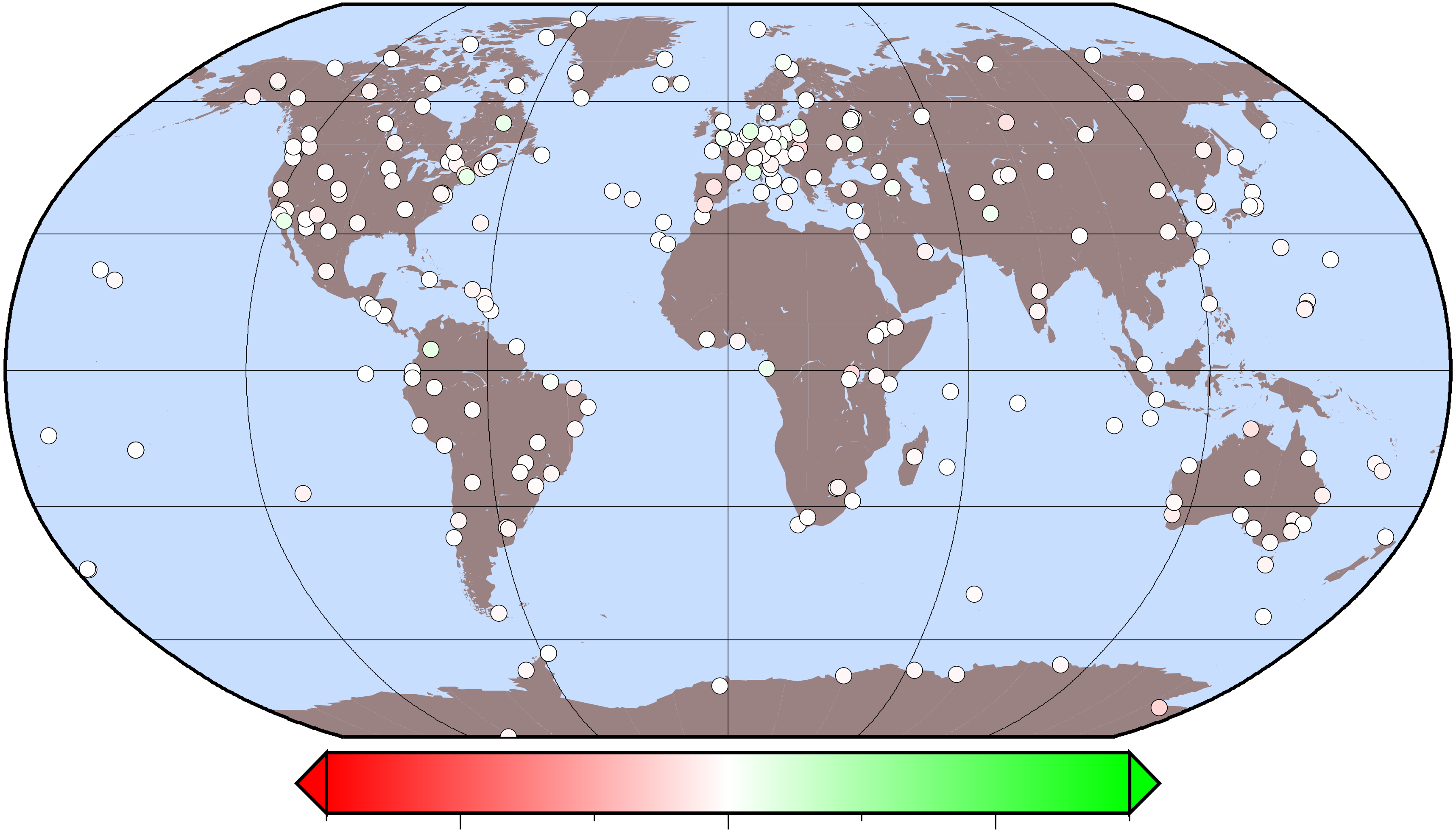


Units: mm

VMF1 is used in both solutions

Influence on the station heights

Height differences between the solutions using *satellite*–specific GMF– and VMF1–based satellite antenna pattern

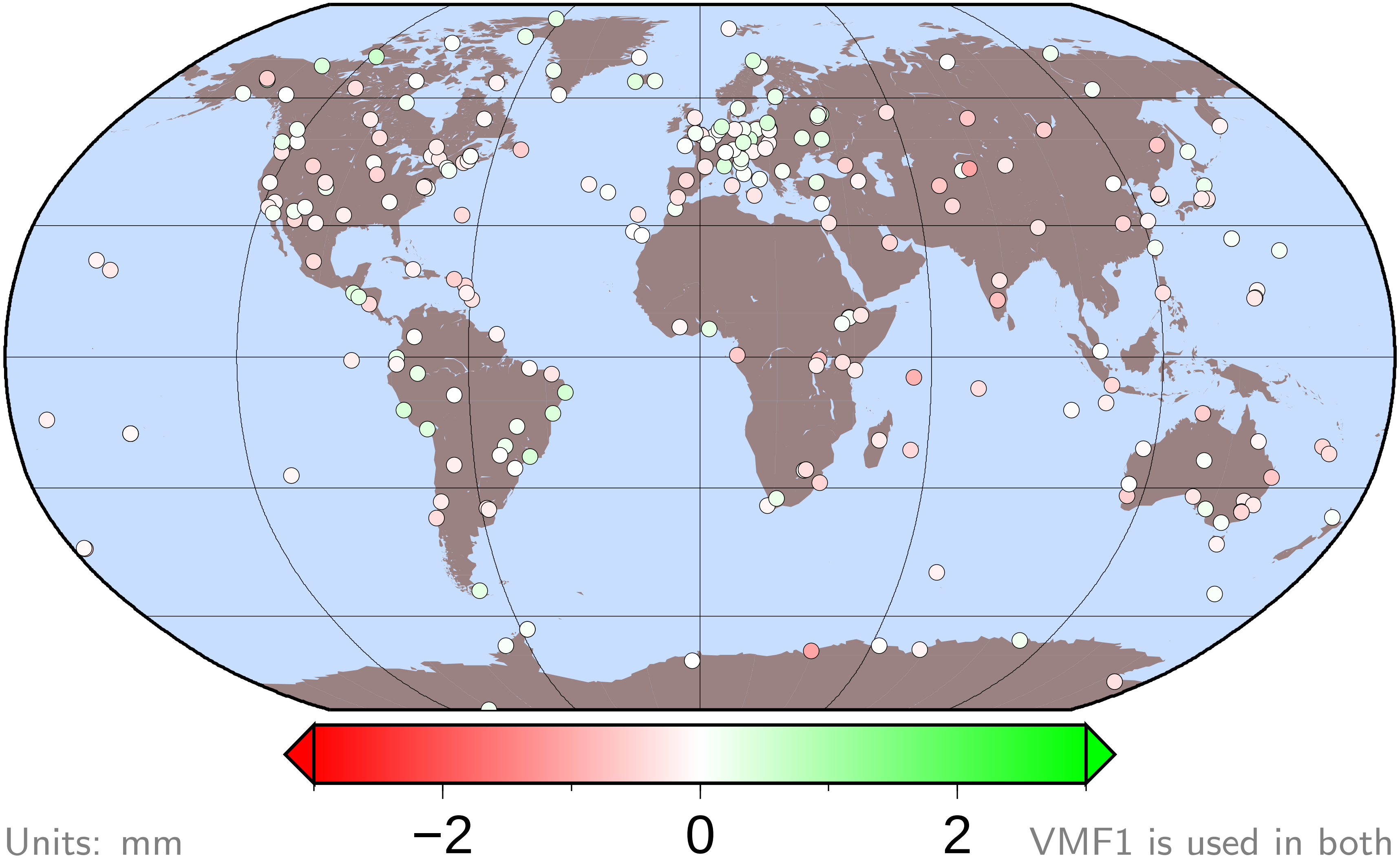


Units: mm

VMF1 is used in both solutions

Influence on the station heights

Height differences between the solutions using *satellite*–specific NMF– and VMF1–based satellite antenna pattern

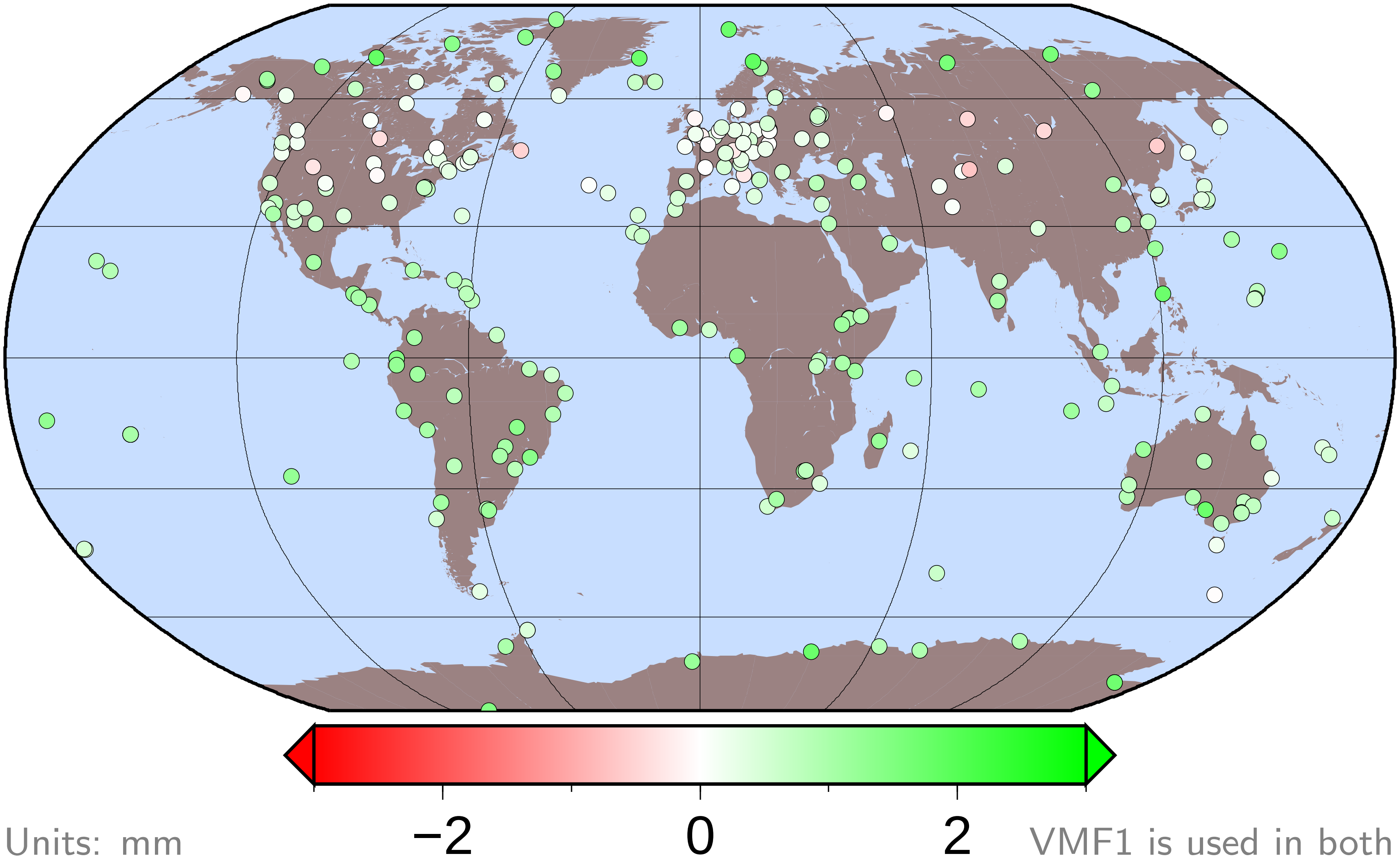


Units: mm

VMF1 is used in both solutions

Influence on the station heights

Height differences between the solutions using *satellite*–specific Jason+GRACE– and VMF1–based satellite antenna pattern

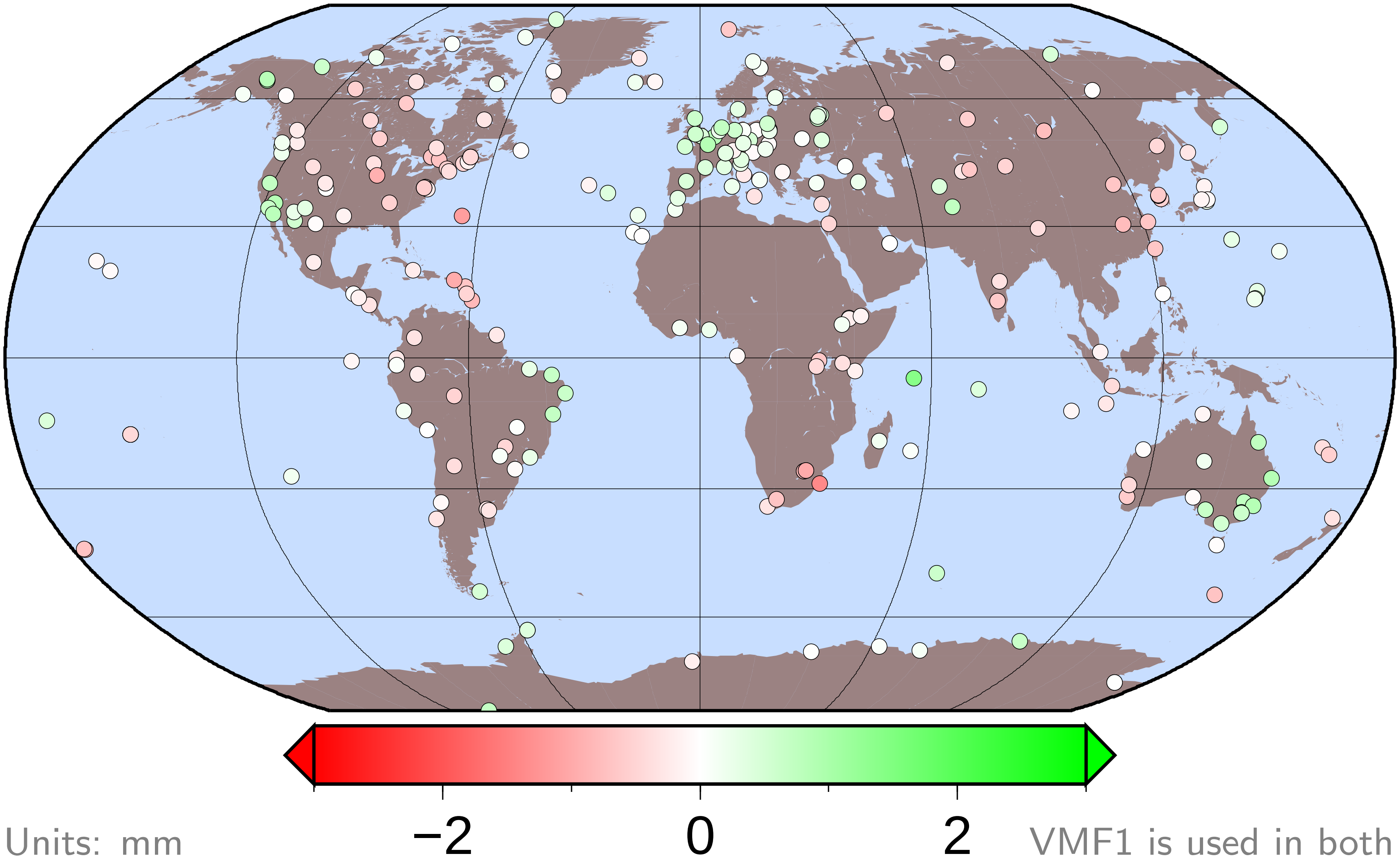


Units: mm

VMF1 is used in both solutions

Influence on the station heights

Height differences between the solutions using *block*–specific GMF– and VMF1–based satellite antenna pattern



Units: mm

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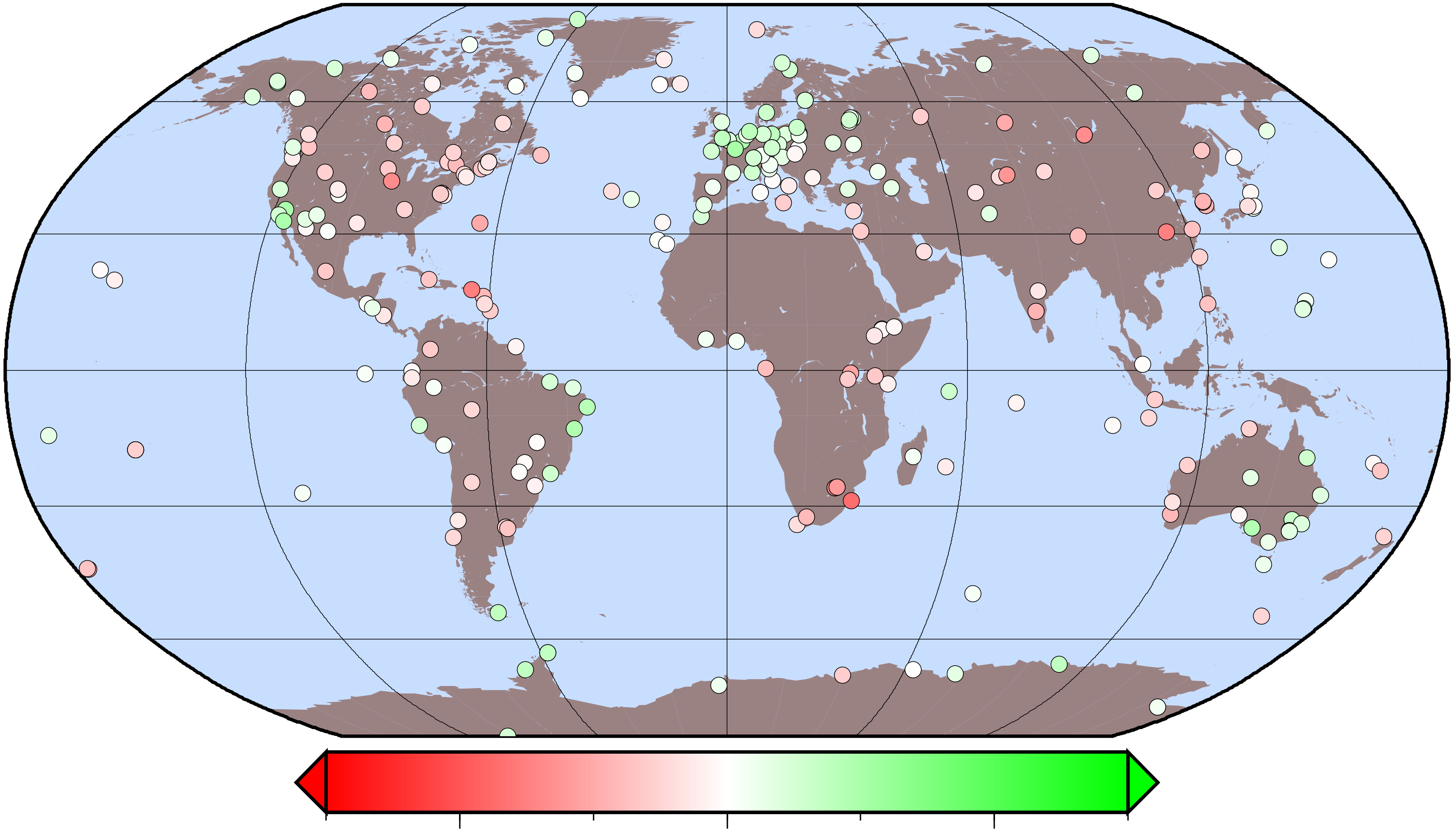
Height differences between the solutions using *block*–specific NMF– and VMF1–based satellite antenna pattern



Units: mm

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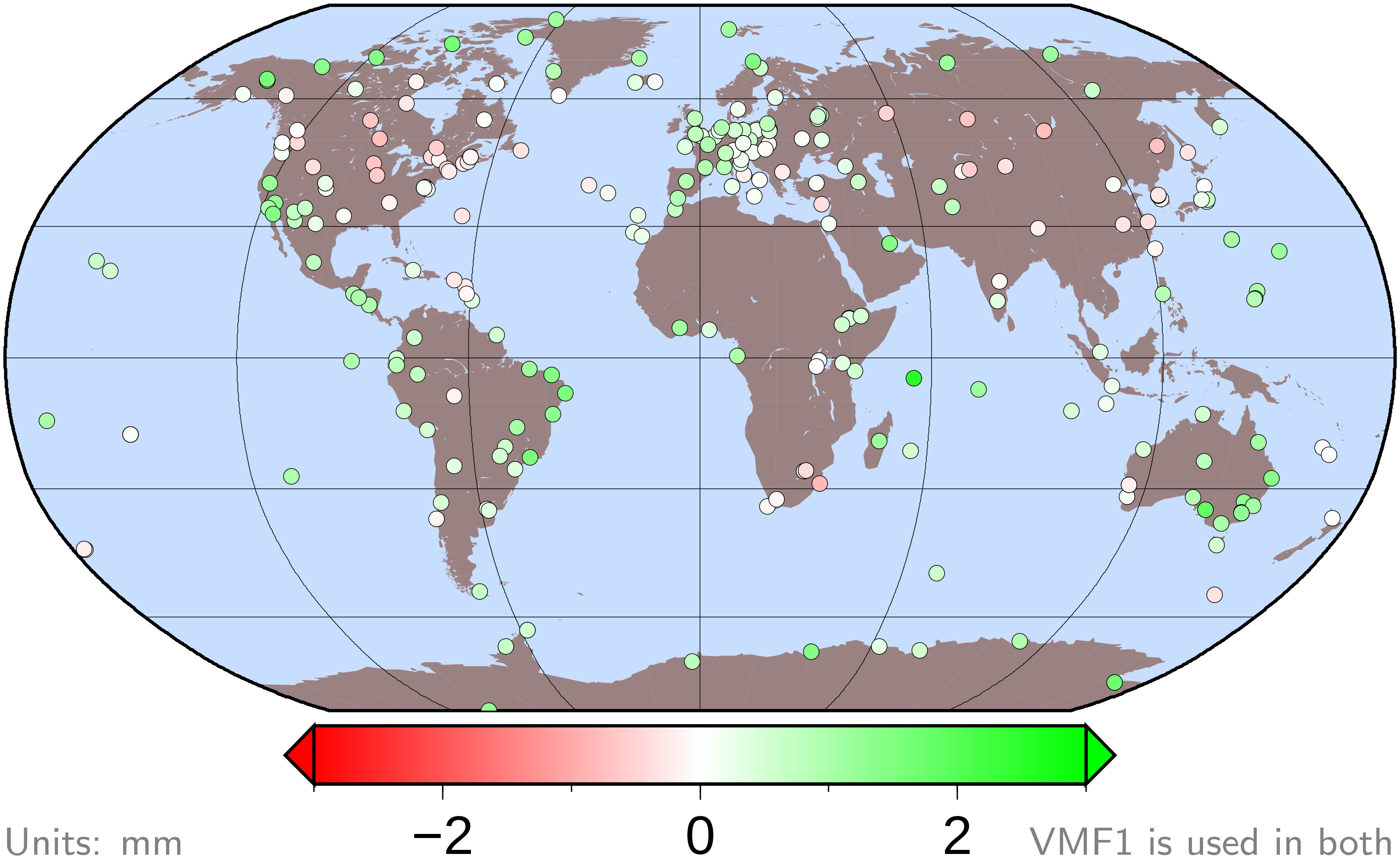

Units: mm

VMF1 is used in both solutions

Answering the questions

- How do different troposphere models affect the satellite antenna phase center?

- Which solution compares best with a LEO–derived solution?

- What is the impact on ground stations, if the troposphere model is inconsistent to the satellite antenna phase center model?

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