Estimation of azimuthal satellite antenna phase center variations

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Outline

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  - Satellite antenna arrays (GPS, GLONASS)
- GPS Block IIA/IIR-A/IIR-BM/IIF
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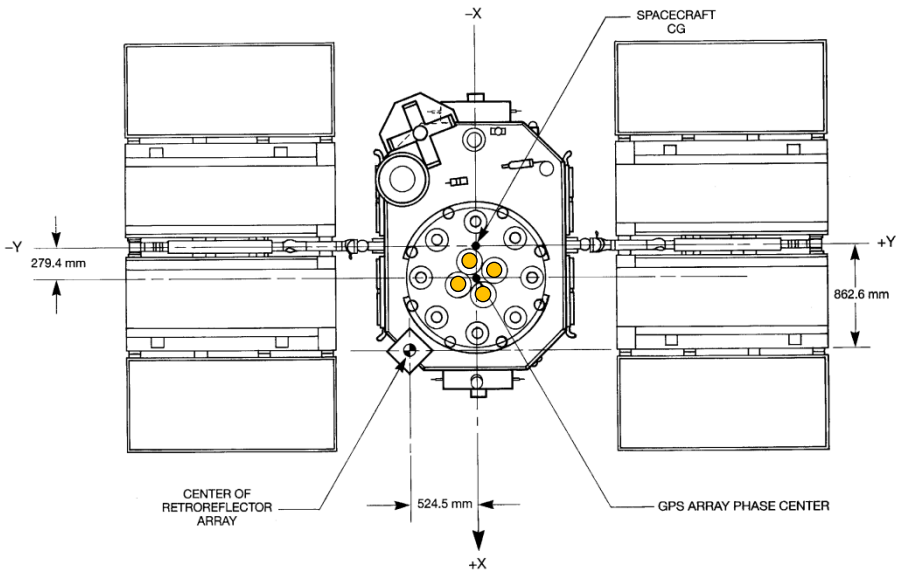
  - Distribution of observations
  - Azimuth-dependent PCVs
  - Internal & external PCV comparisons
- GLONASS-M/GLONASS-K1
- Conclusions

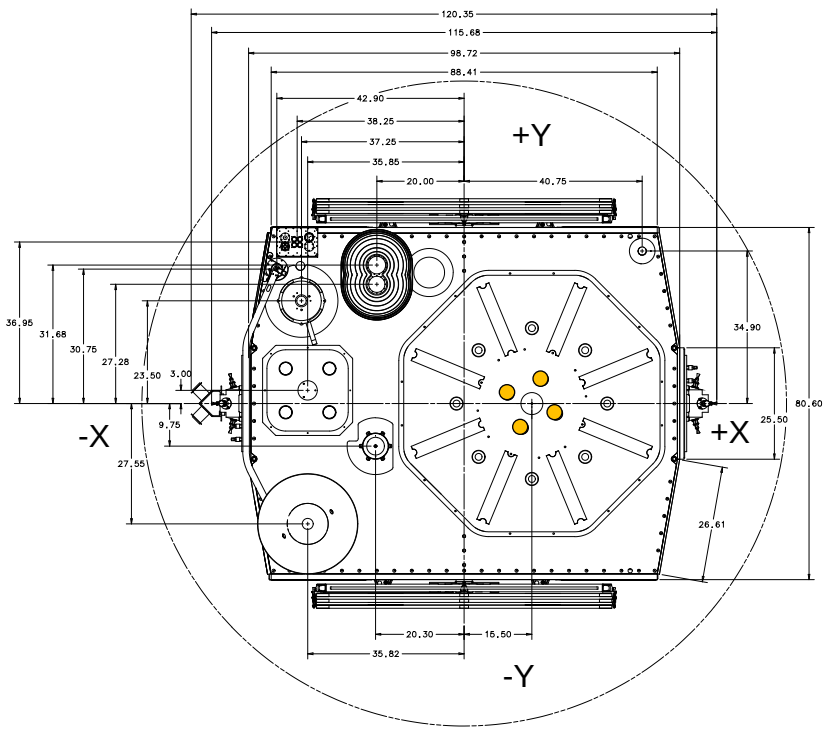
GPS satellite antenna assembly



Block IIA array (Degnan and Pavlis 1994)

- Provision of nearly equal power density to all terrestrial users
- Beam-forming assembly consisting of
  - 12 helical elements
  - 2 concentric circles
  - 4 inner elements, equally spaced
- Azimuth of inner elements wrt +Y axis:
  - IIA: 67.5°, 157.5°, 247.5°, 337.5°
  - IIF: 22.5°, 112.5°, 202.5°, 292.5°
- Major part of total power (IIA: 90 %) supplied to inner quad helices
- Fourfold phase pattern to be expected

GPS satellite antenna assembly

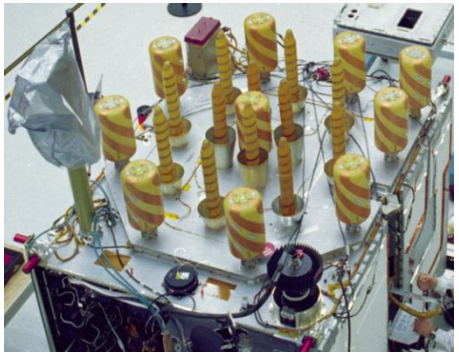


Block IIF array (Boeing)

- Provision of nearly equal power density to all terrestrial users
- Beam-forming assembly consisting of
  - 12 helical elements
  - 2 concentric circles
  - 4 inner elements, equally spaced
- Azimuth of inner elements wrt +Y axis:
  - IIA: 67.5°, 157.5°, 247.5°, 337.5°
  - IIF: 22.5°, 112.5°, 202.5°, 292.5°
- Major part of total power (IIA: 90 %) supplied to inner quad helices
- Fourfold phase pattern to be expected

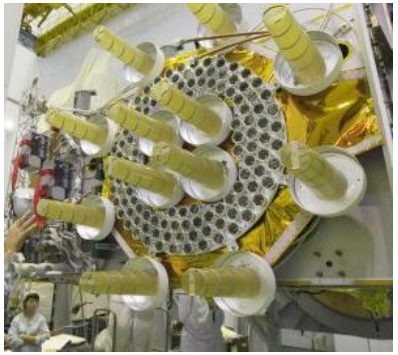
GPS/GLONASS satellite antennas

GPS IIA (Credits: Geo++)



GPS IIR (Credits: Lockheed)

GPS IIF (Credits: Boeing)



GLONASS-M (Reshetnev)

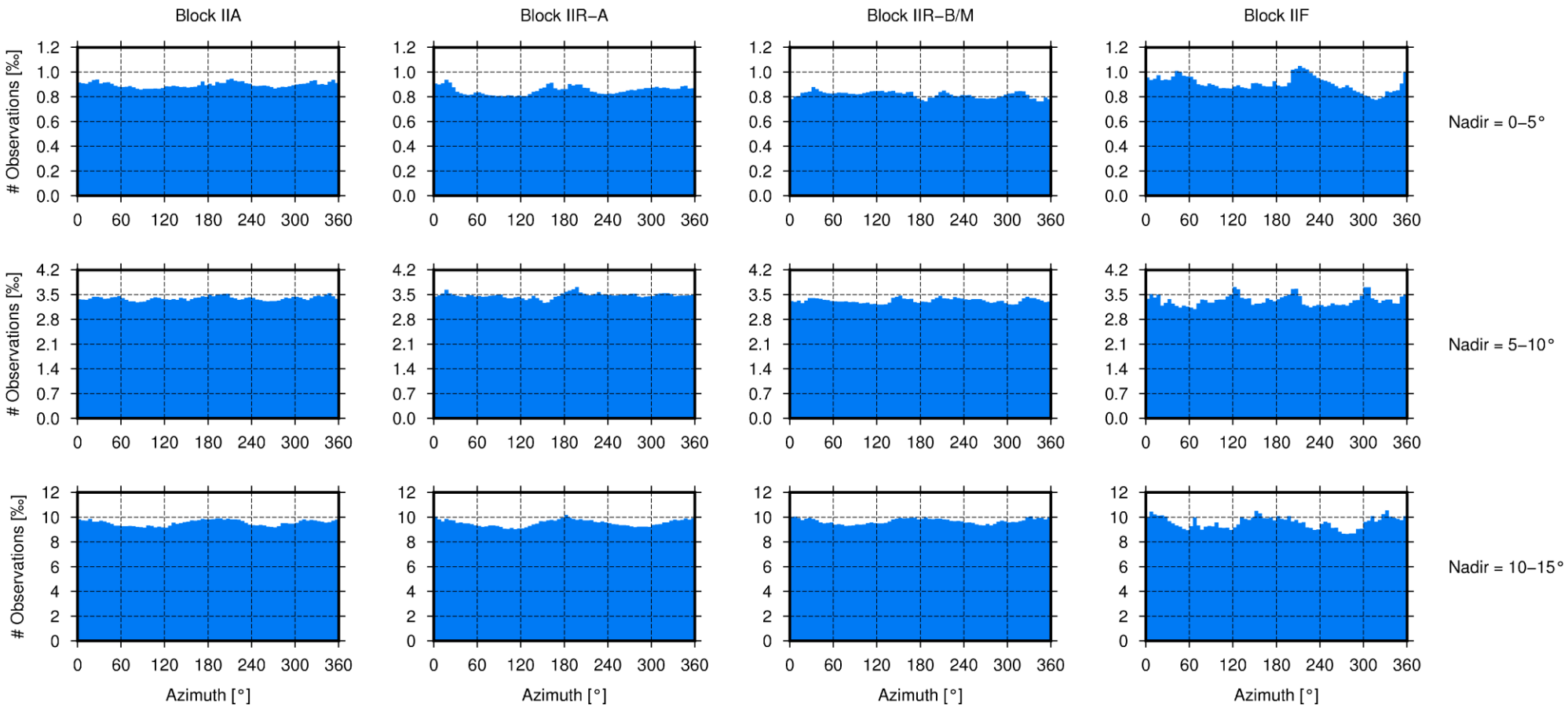
GLONASS-K1 (Reshetnev)

→ 12 element helix design common to all GPS and GLONASS antenna types ←

Processing strategy

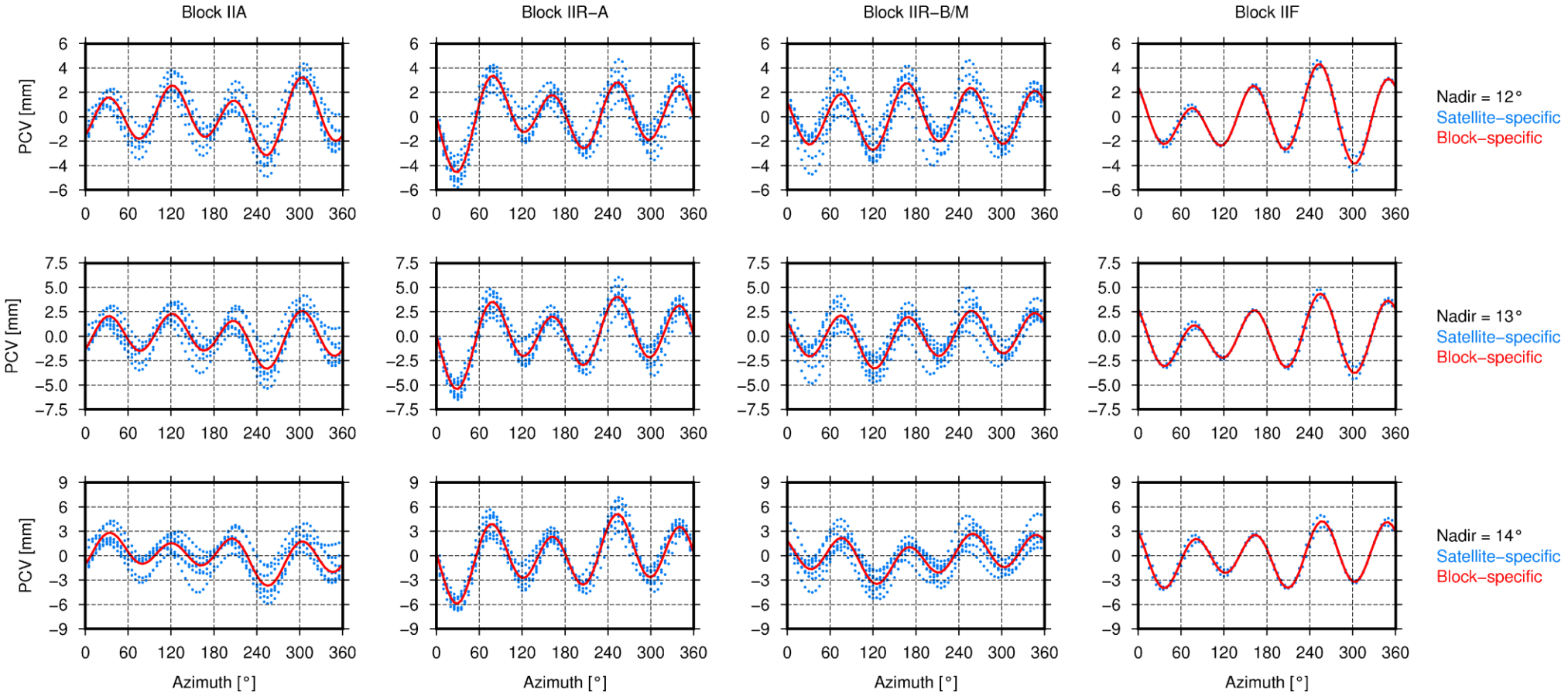
Parameter	IGS – GPS	LEO – GPS
Data	GPS code/phase from 50 IGS sites and Jason-1/2; processed simultaneously	
Time interval	Jan 1, 2004 – Dec 31, 2005 (Jason-1); Jan 1, 2011 – Feb 20, 2012 (Jason-2)	
Sampling rate	60 sec	60 sec
Cut-off angle	0 deg	0 deg
Weighting	$w = \cos^2 z$	$w = \cos^2 z$
Orbits	24-hour arcs; initial positions/velocities; 3 constant plus 2 periodic RPRs; 3 along-track CPRs	24-hour arcs; initial positions/velocities; 4 periodic CPRs every 12 hours; 5 drag parameters every 24 hours
Earth rotation	Daily pole coordinates and drifts, UT1 and LOD are estimated	
Ambiguities	Resolved	Not resolved
Satellite antennas	Spherical harmonics (8, 4) for GPS & LEOs; GPS PCVs minimized over 0-14° nadir	
Station antennas	PCOs/PCVs fixed to igs08.atx	-
Coordinates	No-net-rotation constraint applied	-
Troposphere	1-hourly ZPDs / daily gradients estimated	-

Distribution of observations



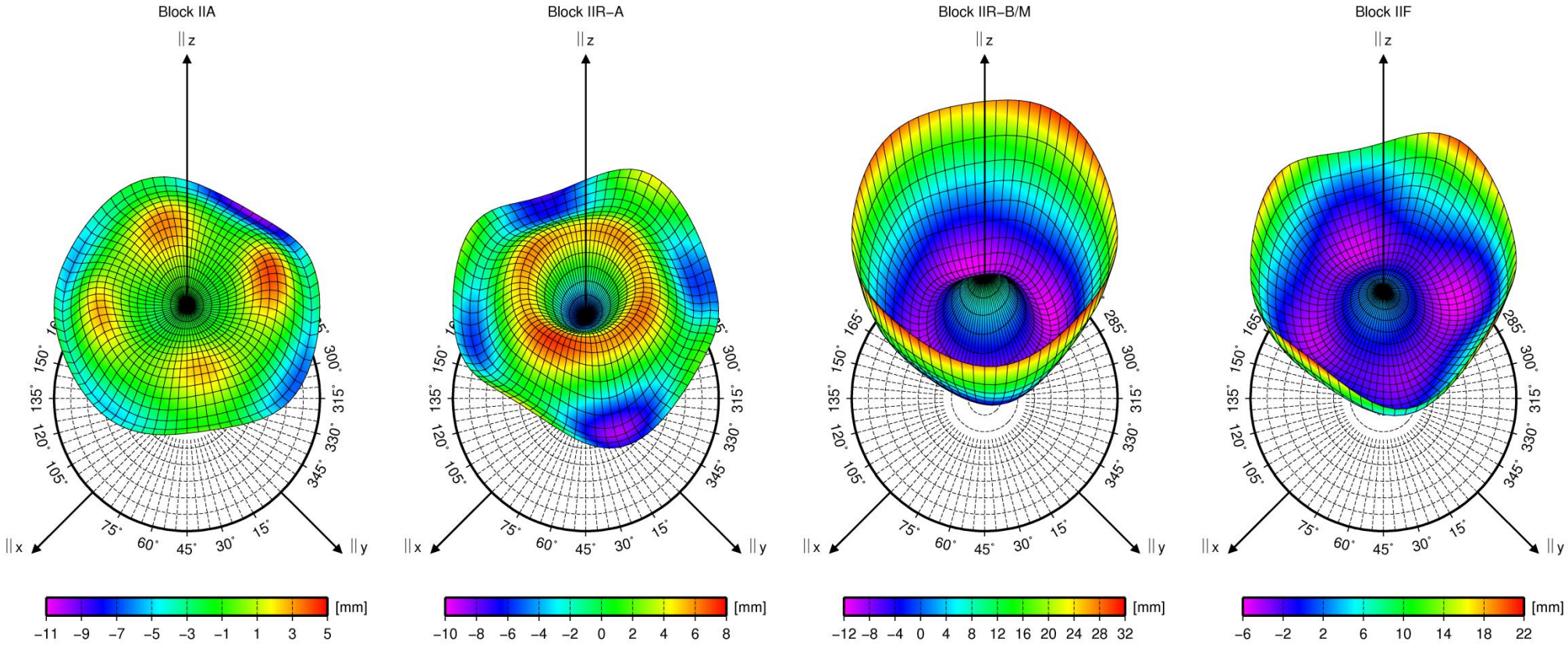
→ Observations evenly distributed across azimuthal range ←

Satellite- vs. block-specific PCVs



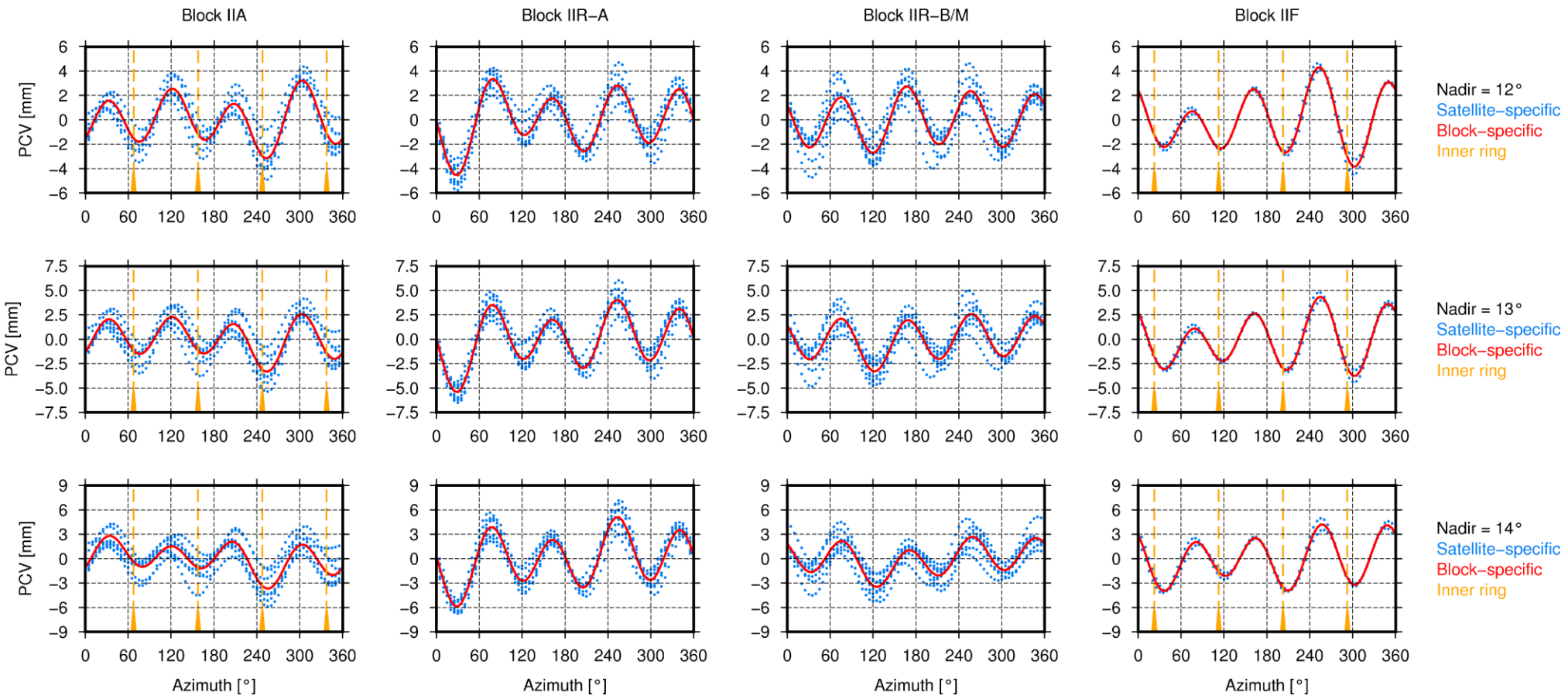
→ Reasonable agreement both in phase and amplitude allow for block-specific PCVs ←

Block-specific PCVs (3D)



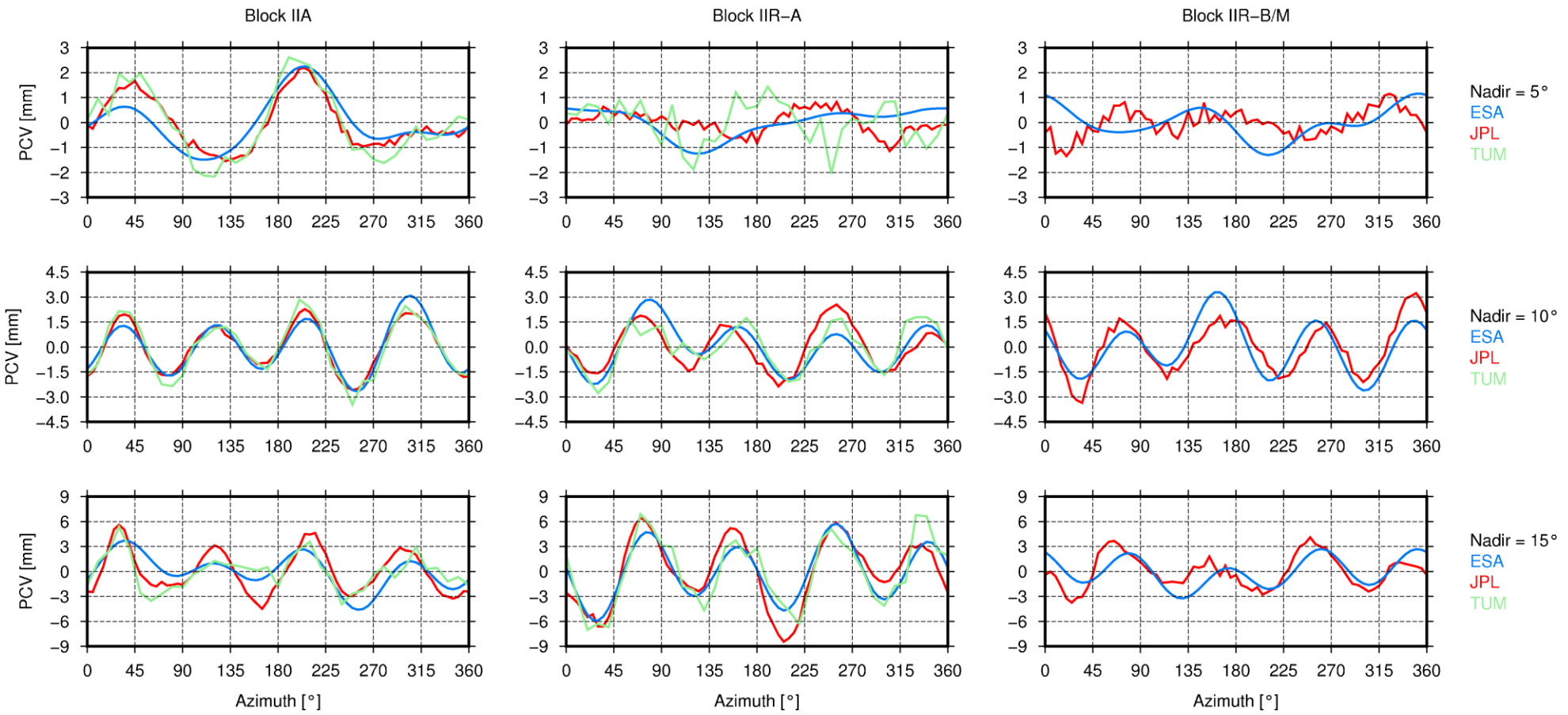
→ Fourfold pattern apparent in PCVs of all four GPS antenna types ←

Impact of antenna array geometry



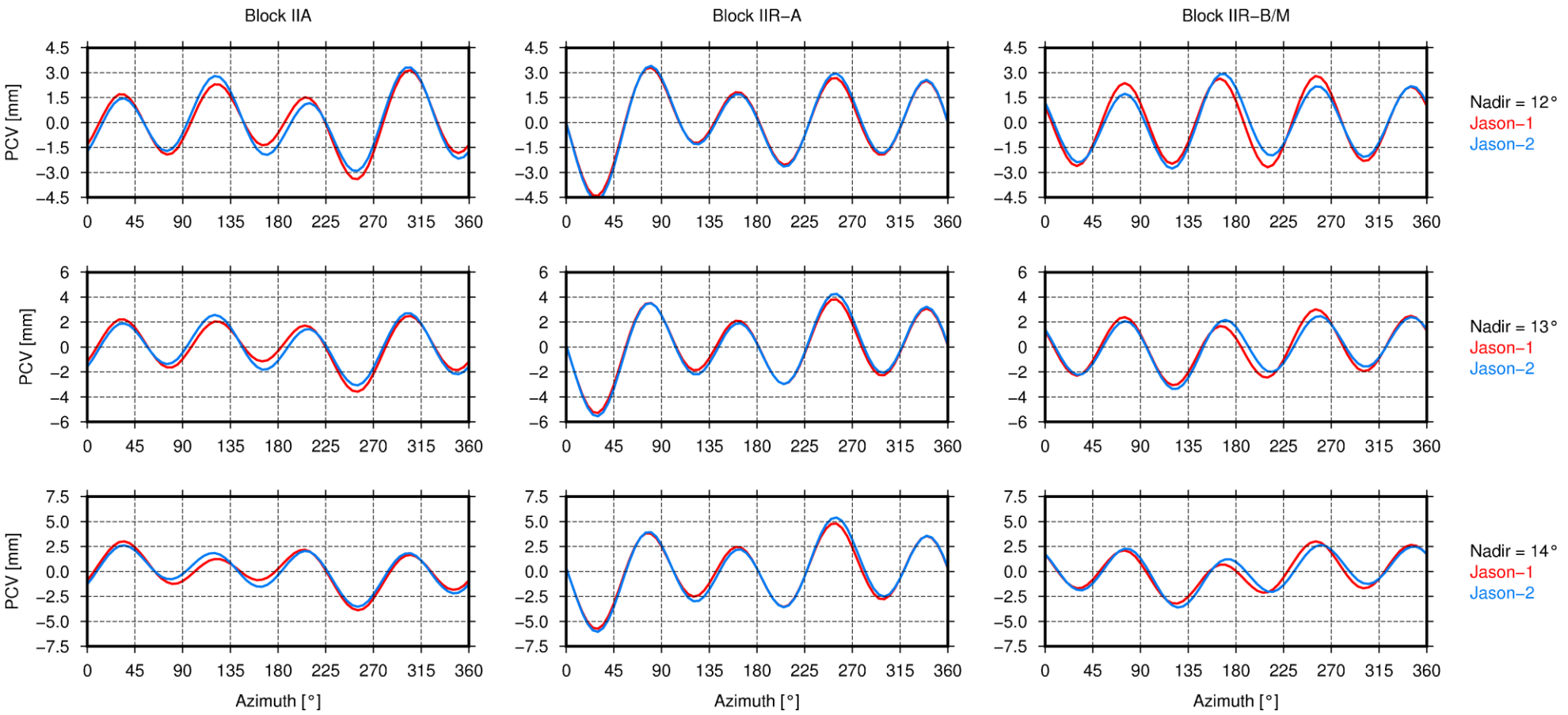
→ IIA/IIF PCV minima closely match geometry of inner four antenna elements ←

External consistency (ESA vs. JPL vs. TUM)



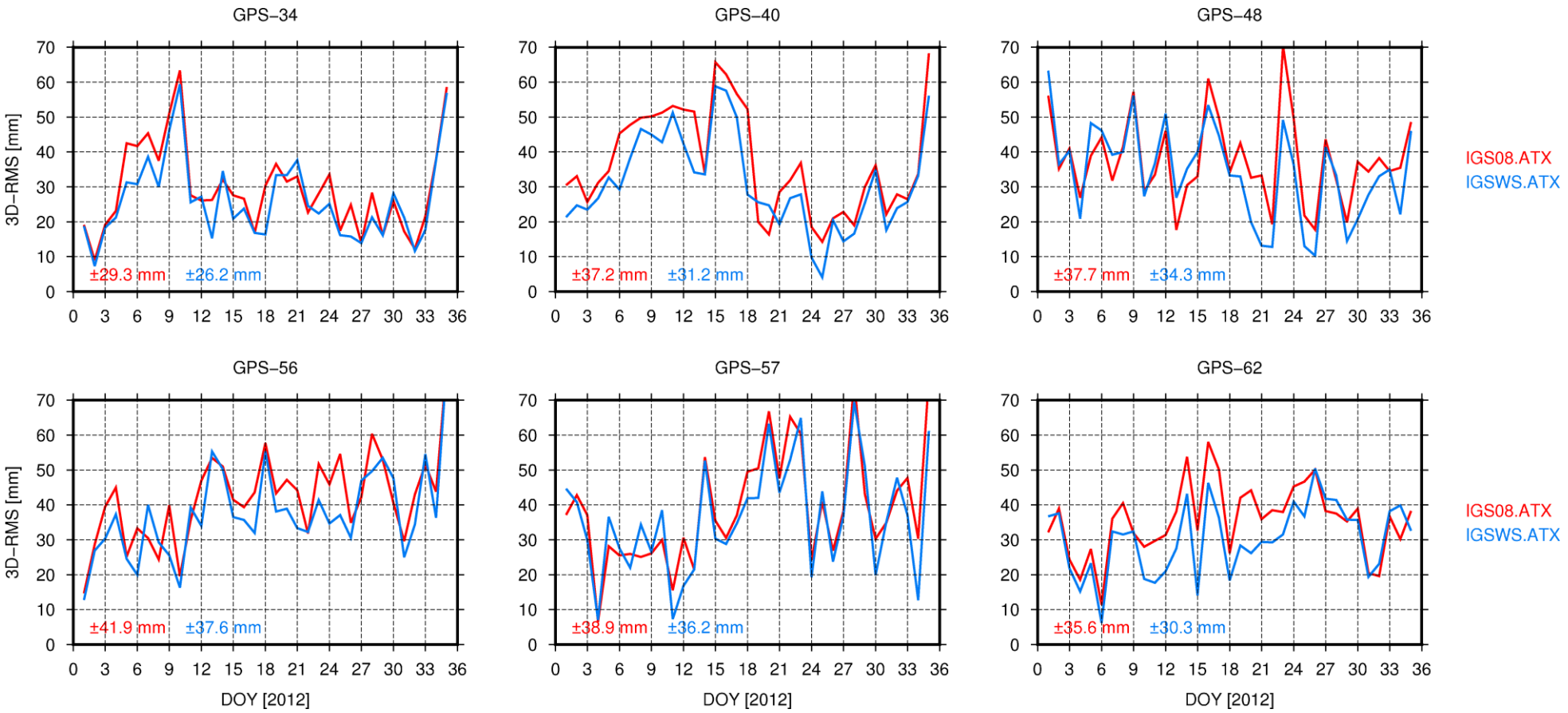
→ Reasonable agreement between all three analysis centers ←

Internal consistency (Jason-1 vs. Jason-2)



→ Excellent agreement both in phase and amplitude for all three block types ←

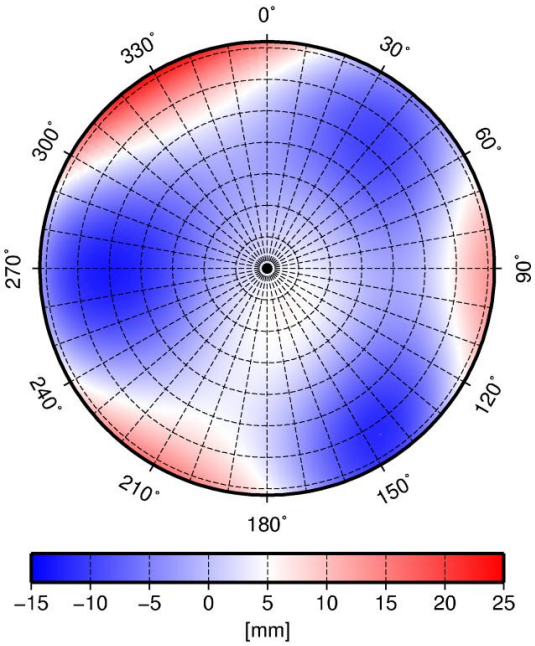
Impact on internal orbit consistency

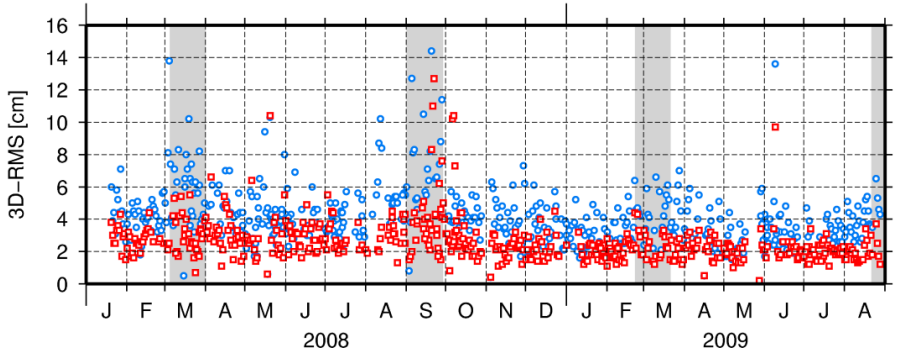


→ Significant improvement can be noticed, but only for certain orbit overlaps ←

GLONASS-M/GLONASS-K1

- Despite array design, no azimuthal PCVs found
- "Out-of-family" PCVs detected for SVN 714
- Threefold phase pattern, almost symmetrical with variations ranging from -15 to +25 mm
- On-board antenna is of same design as other GLONASS-M antennas
- Pattern probably related to L2 signal anomaly
- Significantly impacts orbit quality (see overlap RMS in right figure)





Dilssner et al., JoG 2010

Conclusions

- GPS:
  - Azimuthal PCVs of up to ±6 mm found for all antenna types
  - Reasonable agreement with JPL/TUM estimates (Miami 2008)
  - Impact on GNSS parameters to be further investigated; orbit quality exhibits significant improvements, but also shows degradation
- GLONASS:
  - No azimuth-dependences identified, neither for any S/C of the M series nor for the recently launched GLONASS-K1 prototype
  - SVN 714 remains the only exception
- Applying azimuthal PCV corrections requires precise knowledge of S/C yaw attitude at all times, also during eclipse maneuvers
  (see *GNSS satellite attitude characteristics* talk by Dilssner et al.)