Combining terrestrial and LEO data to extend the GPS satellite antenna patterns to nadir angles beyond 14°

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AGU
Fall Meeting
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Deutsches Zentrum
für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

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EUMETSAT

European Organisation for the Exploitation of Meteorological Satellites

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Introduction

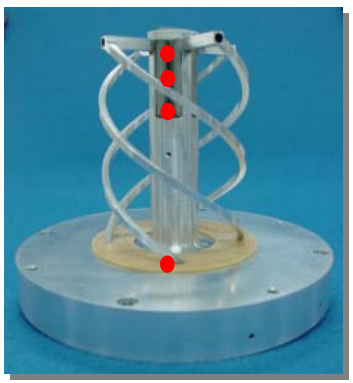
Phase center variations (PCVs) of GPS transmitter antennas, e.g., as provided by the IGS, are restricted to nadir angles <=14°

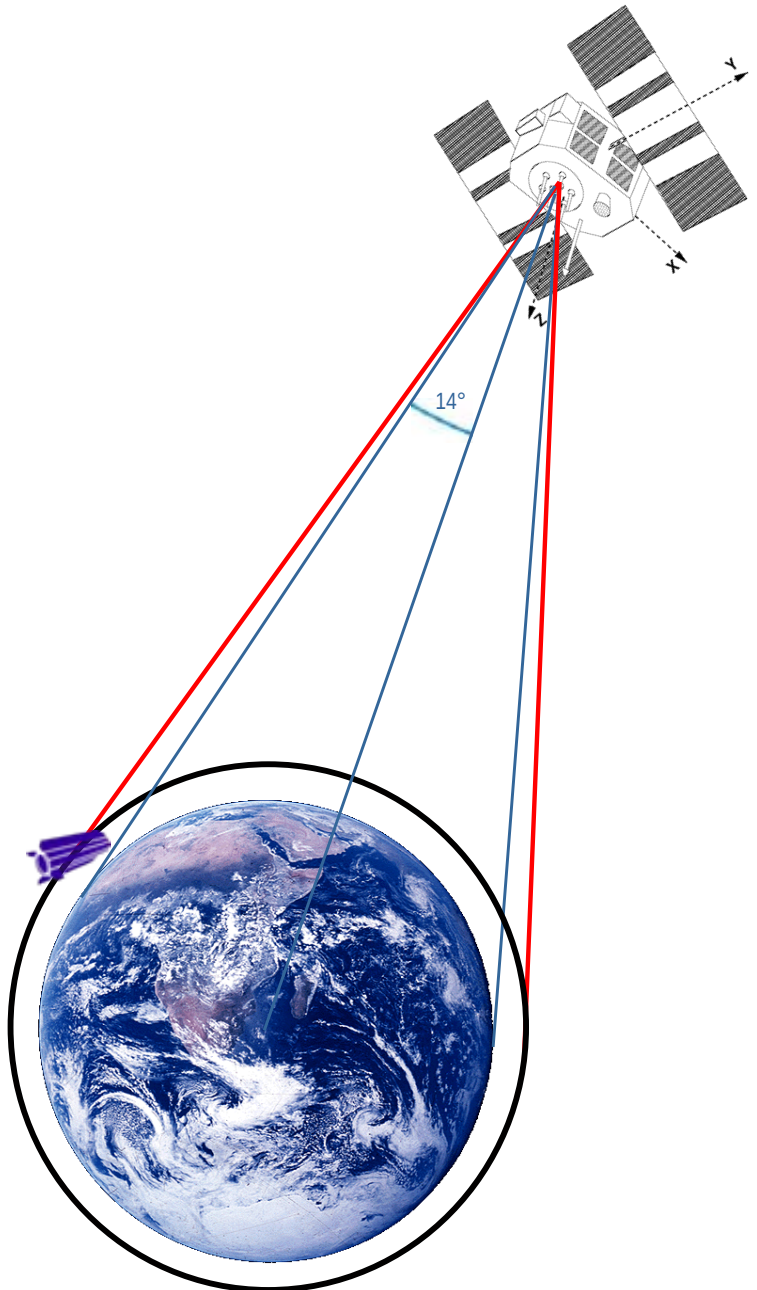
GPS data from Low Earth Orbiters (LEOs) may be used to extend the GPS PCVs to nadir angles <= 17°

LEO phase center offsets (PCOs) have to be precisely known, LEO PCVs need to be co-estimated

L2 PCO
L1 PCO
Lc PCO

antenna reference point





Input data & products

- LEO GPS data, undifferenced ionosphere-free
  (Jason-2, GRACE-A/B, GOCE, MetOp-A, from 2009)
- GPS orbits and clock corrections from the CODE reprocessing, introduced as known
  (consistent with PCOs & PCVs from igs08.atx)
- LEO orbits from AIUB relying on the CODE reprocessed products, introduced as known
  (not based on empirical PCVs)
- GPS PCOs and GPS PCVs from igs08.atx, used as a priori values for the transmitter antennas
  (PCV values extended beyond 14° with constant values)
- LEO PCOs used at AIUB for POD, introduced as known for the LEO receiver antennas
  (no a priori LEO PCVs are used)

Estimated parameters & constraints

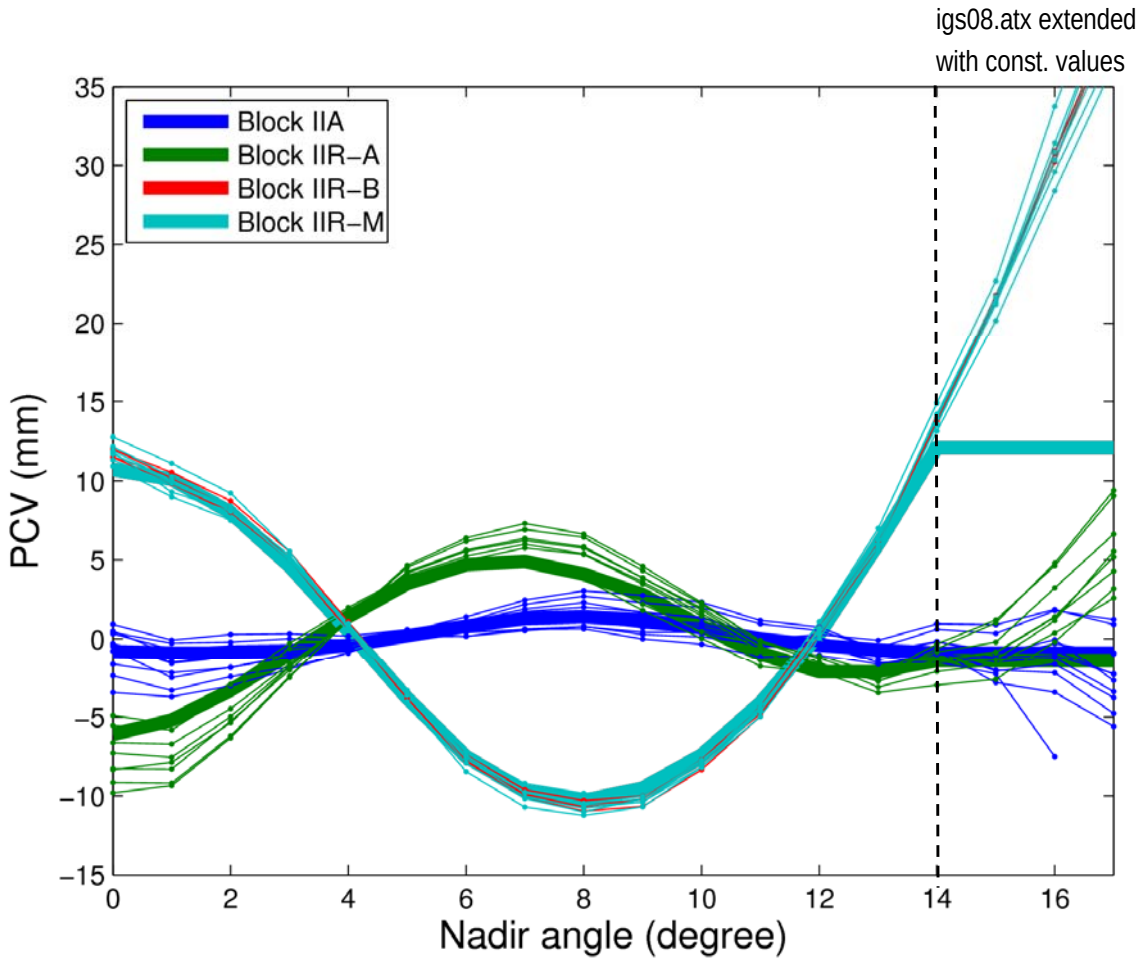
- PCVs for the GPS transmitter antennas
  (nadir-dependent, piecewise linear, satellite-specific)
  - zero-mean condition (for nadir angles <= 12°)
  - PCVs of two Block IIA SVs constrained to a priori due to the simultaneous estimation of LEO PCVs

- PCVs for the LEO receiver antennas
  (5°x 5° grid, piecewise linear, LEO-specific)
  - zero-mean condition over all grid points
  - weak overall constraint (in principle not necessary, just used to avoid unreasonably large values of weakly observed grid points)

Normal equations are assembled for different LEOs to solve for the PCVs.

LEO-only solution

PCVs compared to igs08.atx



Data used:

Jason-2

MetOp-A

GRACE-A

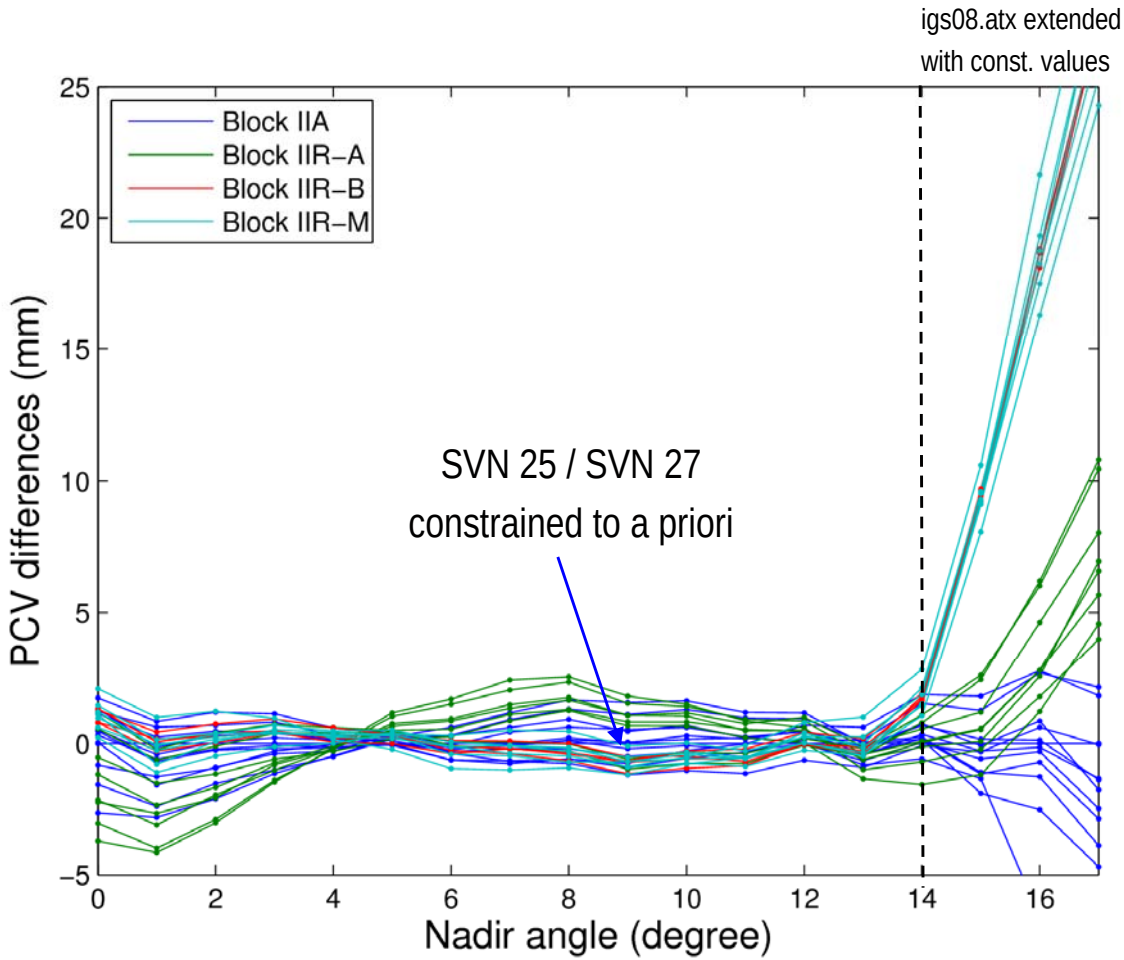
GRACE-B

GOCE

Large differences wrt a priori PCVs beyond 14° (constant extension)

LEO-only solution

PCV differences wrt igs08.atx



Data used:

Jason-2

MetOp-A

GRACE-A

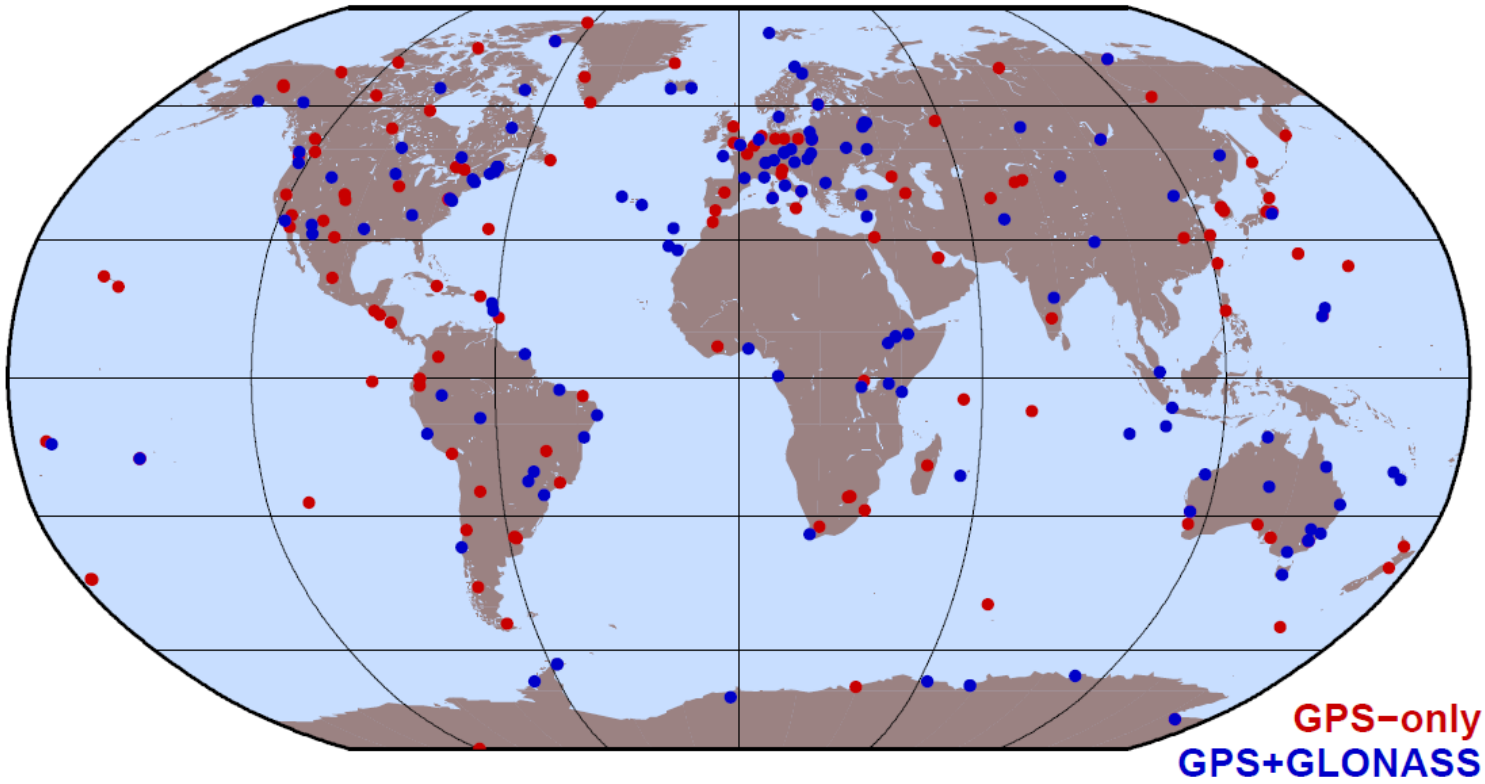
GRACE-B

GOCE

Differences of 2-3 mm wrt block-specific values of igs08.atx below 14°

Terrestrial solution

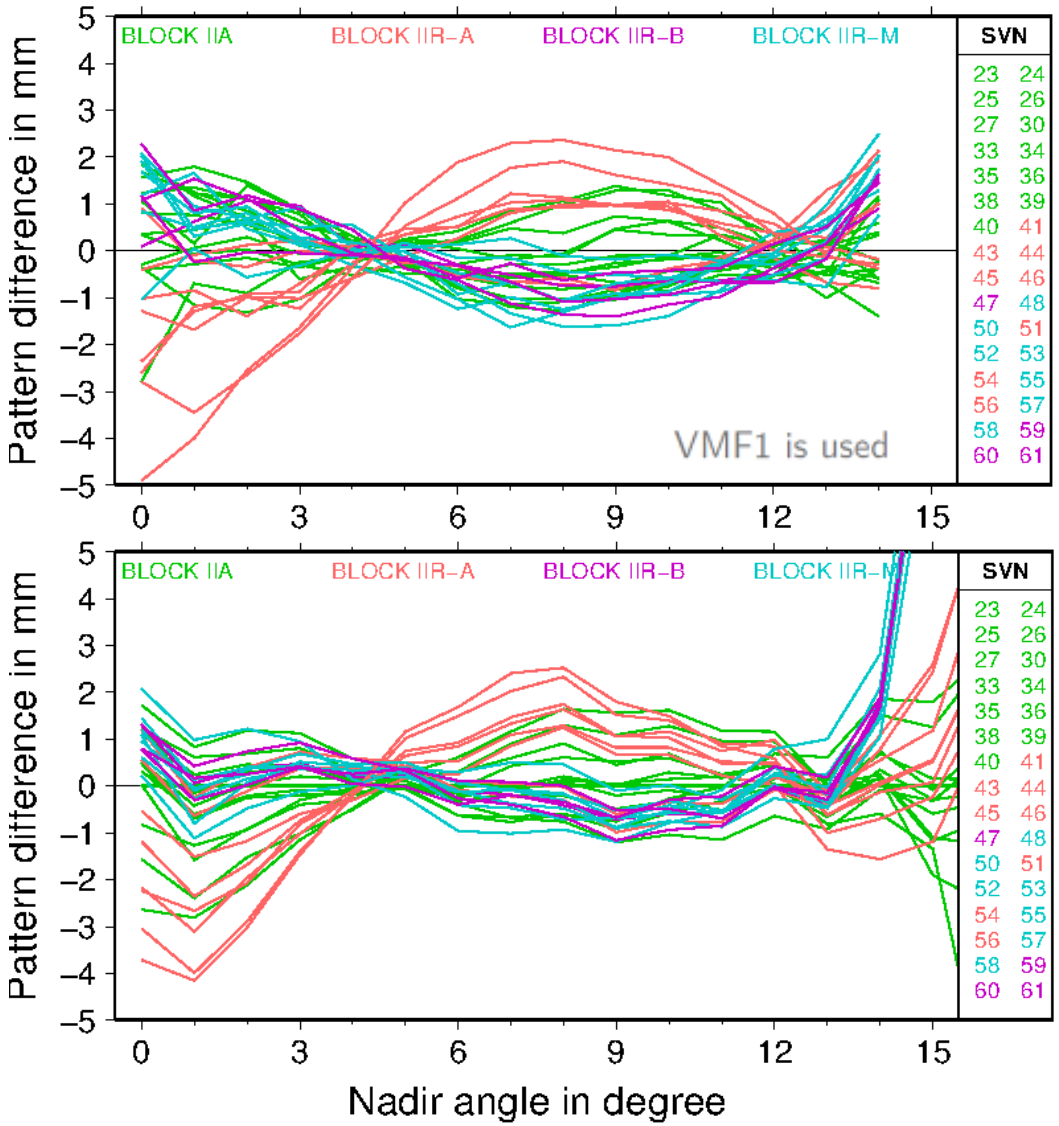
Station network



Data from 2009-2010 used for PCV estimation (IGS08 frame used)

Solution comparison

PCV differences wrt igs08.atx



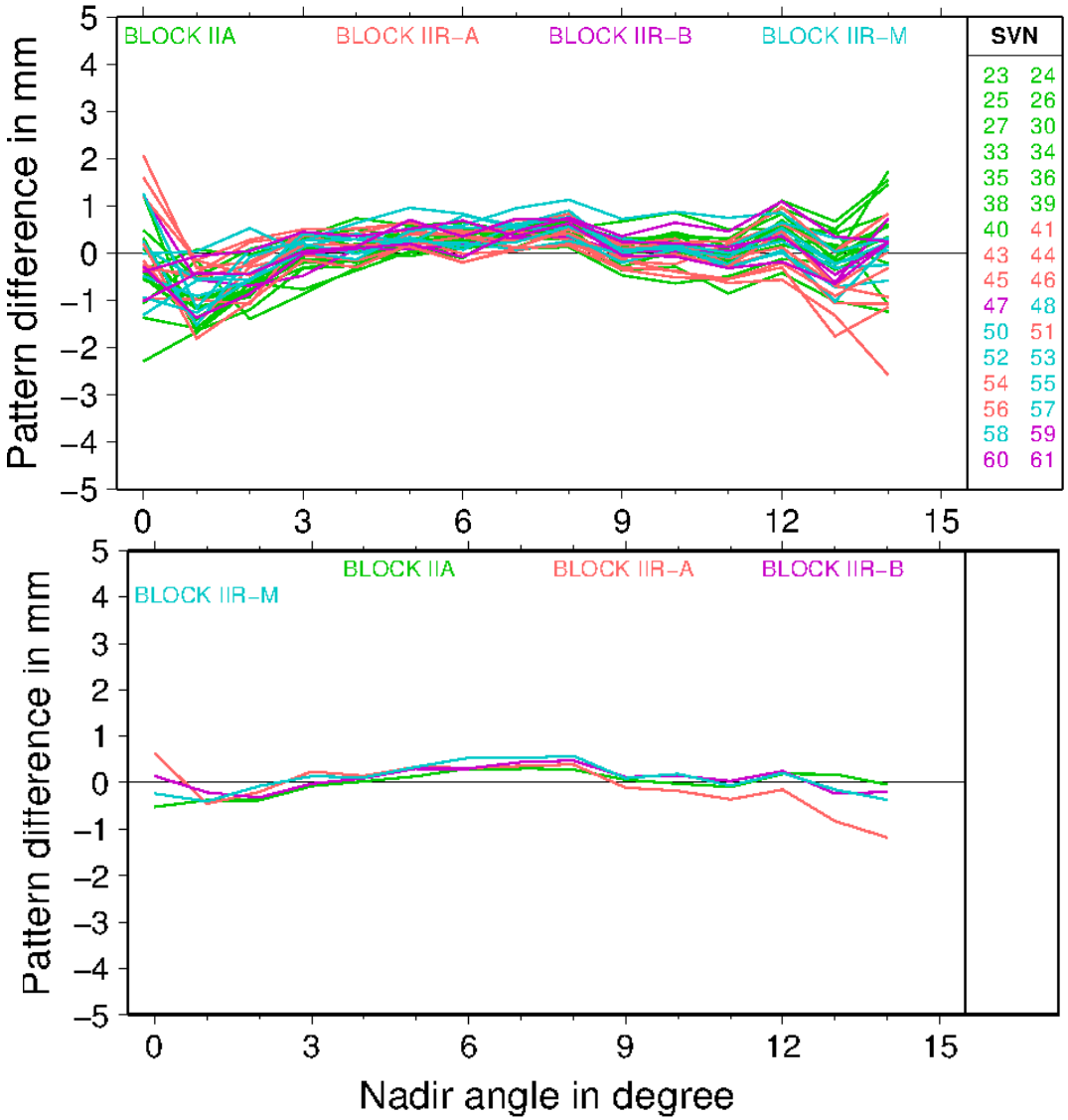
Terrestrial data

LEO data

Both solutions detect similar differences to the block-specific model

Solution comparison

LEO-derived vs. terrestrial solution



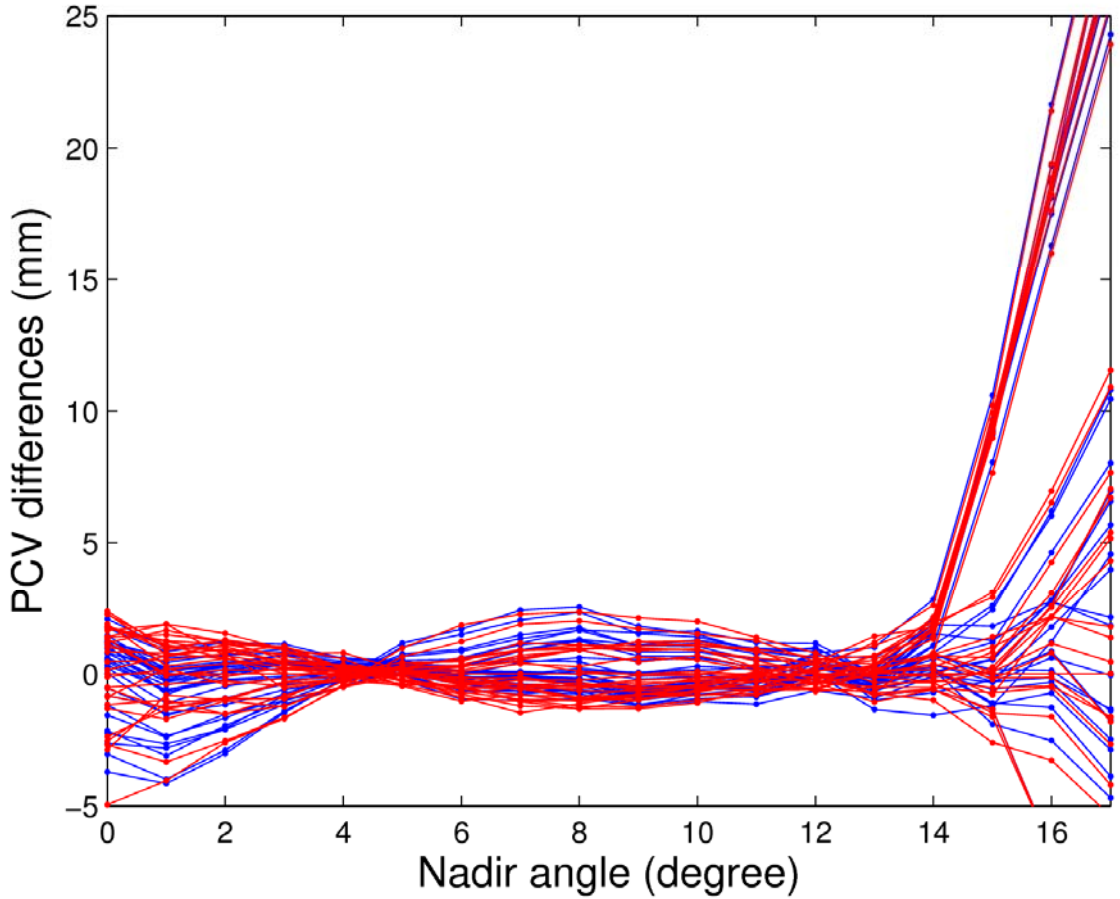
Satellite-specific

Block-specific

Excellent agreement between block-specific solutions below 14°

Combined solution

by normal equation stacking



Normal eqns:

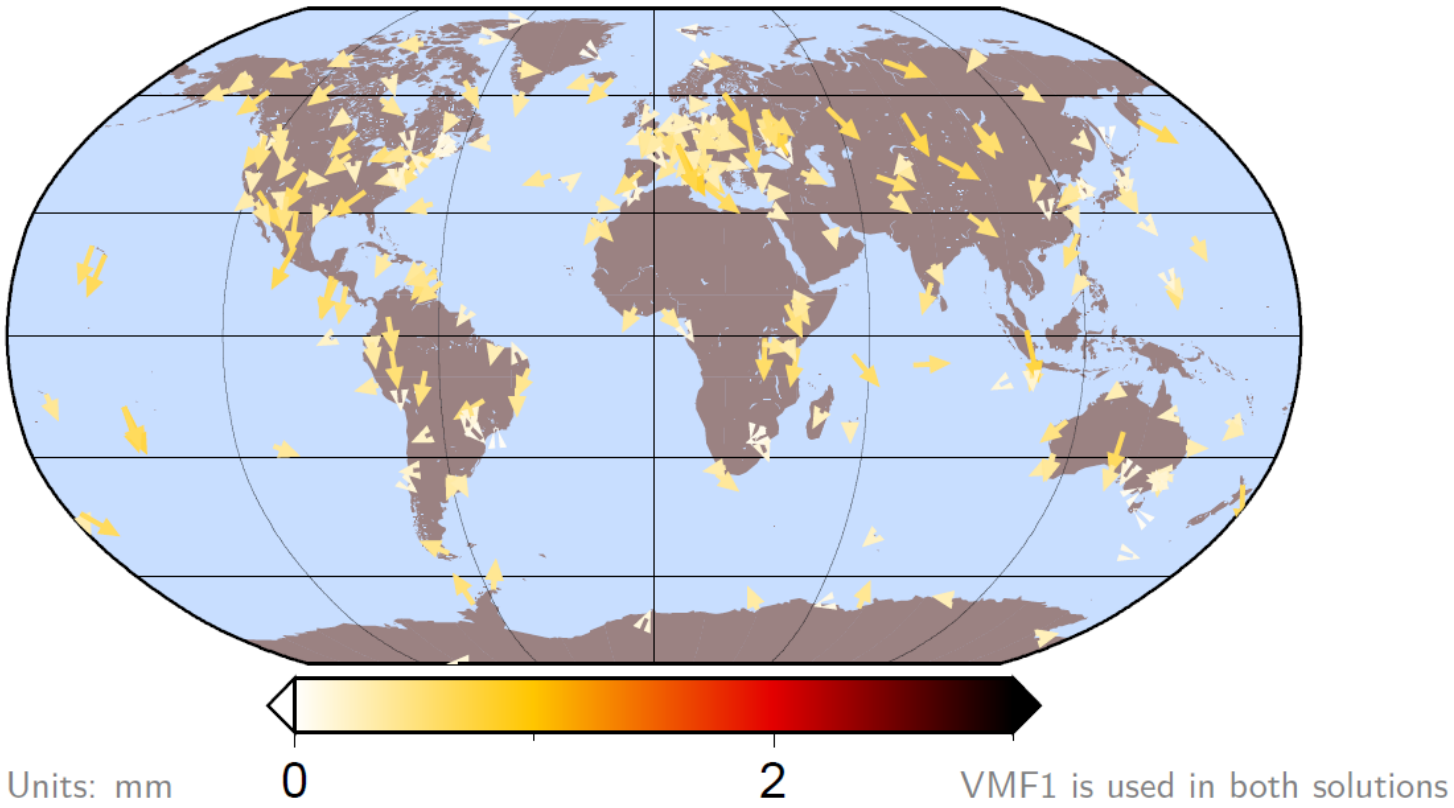
LEO-derived

LEO & terrestrial

Combination improves LEO-derived estimates for low nadir angles

Impact of LEO-derived PCVs

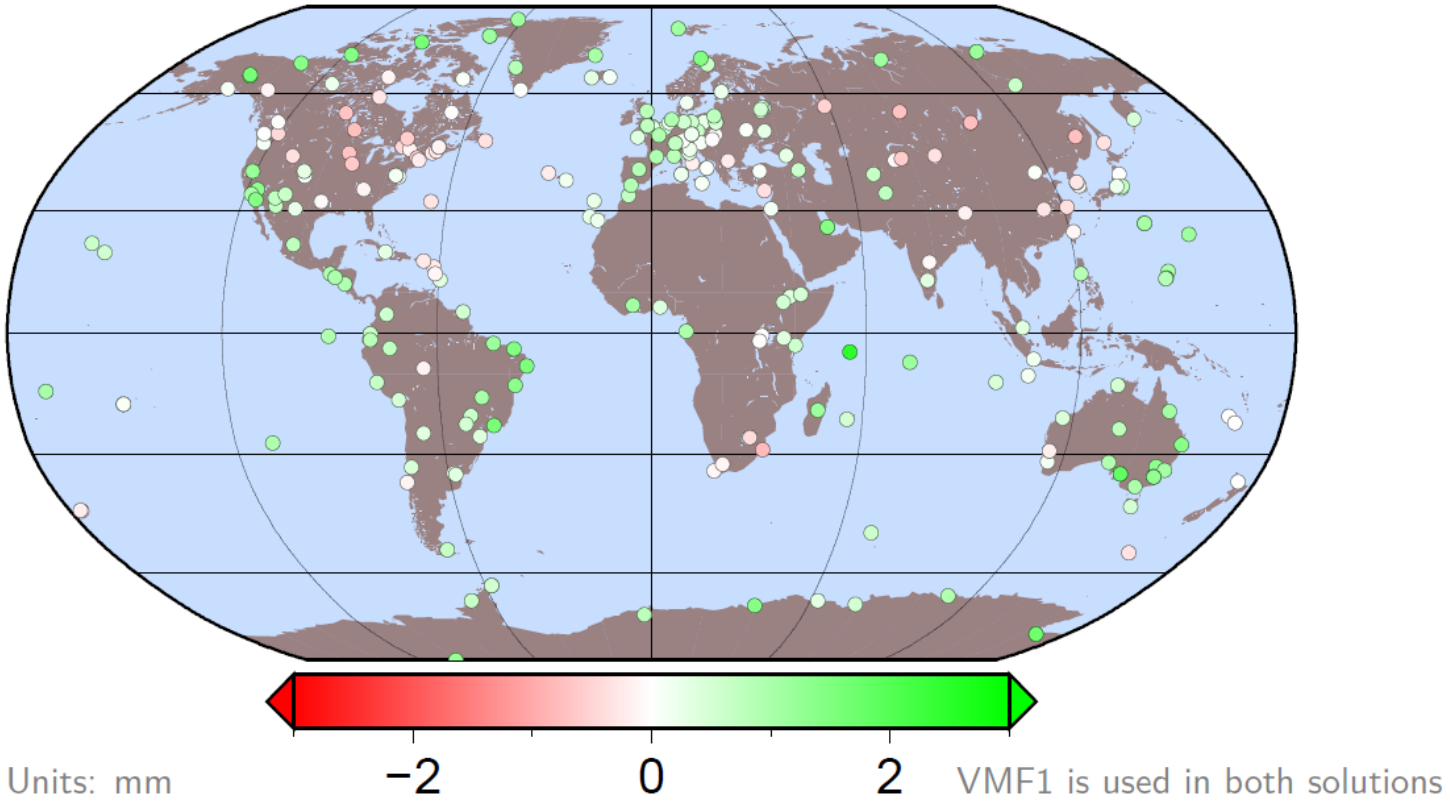
on coordinate results of a network solution



Horizontal positions are affected by less than 1mm

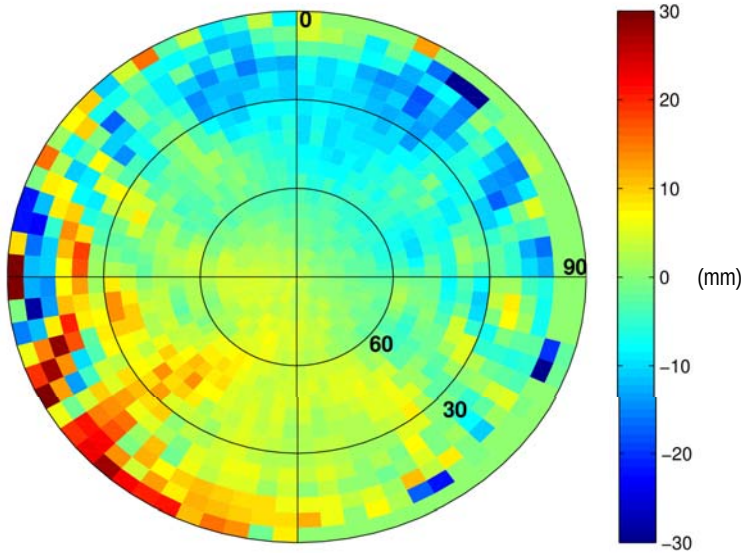
Impact of LEO-derived PCVs

on coordinate results of a network solution

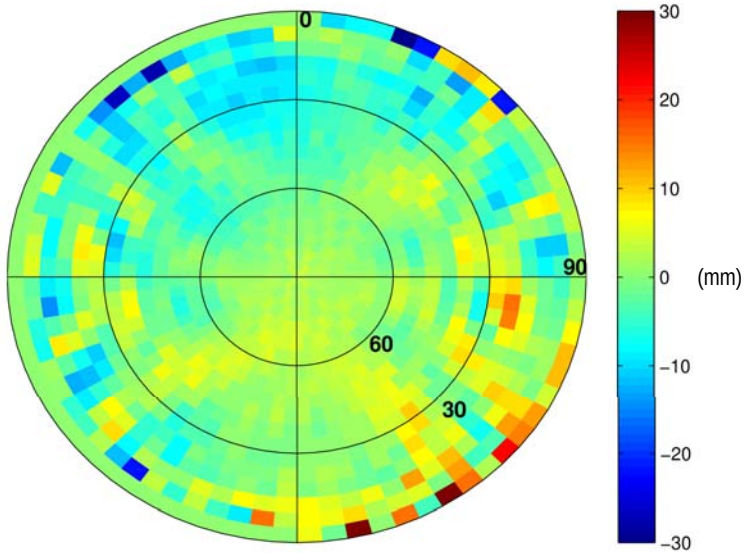


Heights are affected by less than 2mm

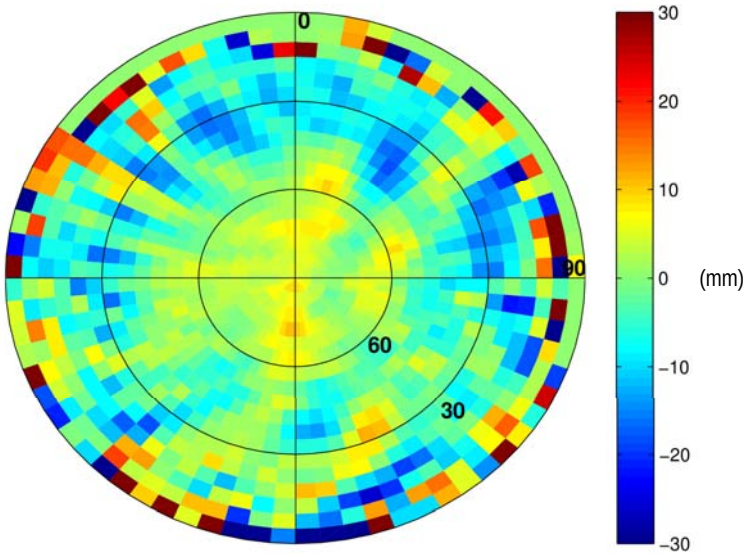
Estimated LEO PCVs



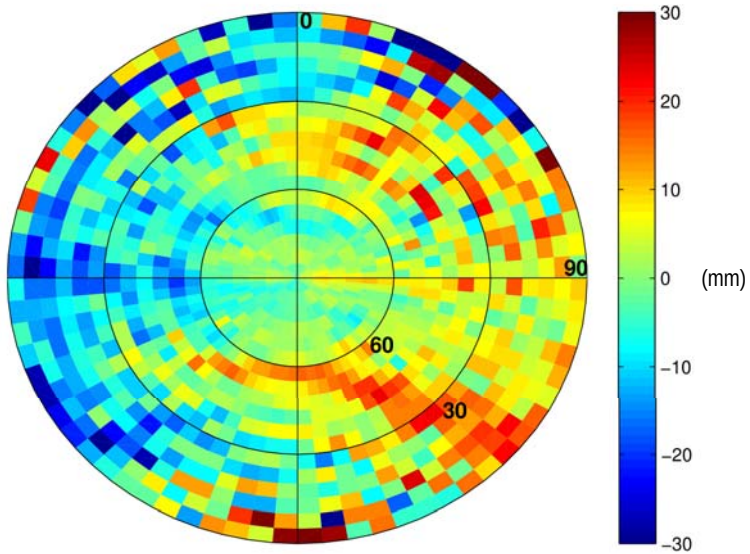
GRACE-A



GRACE-B



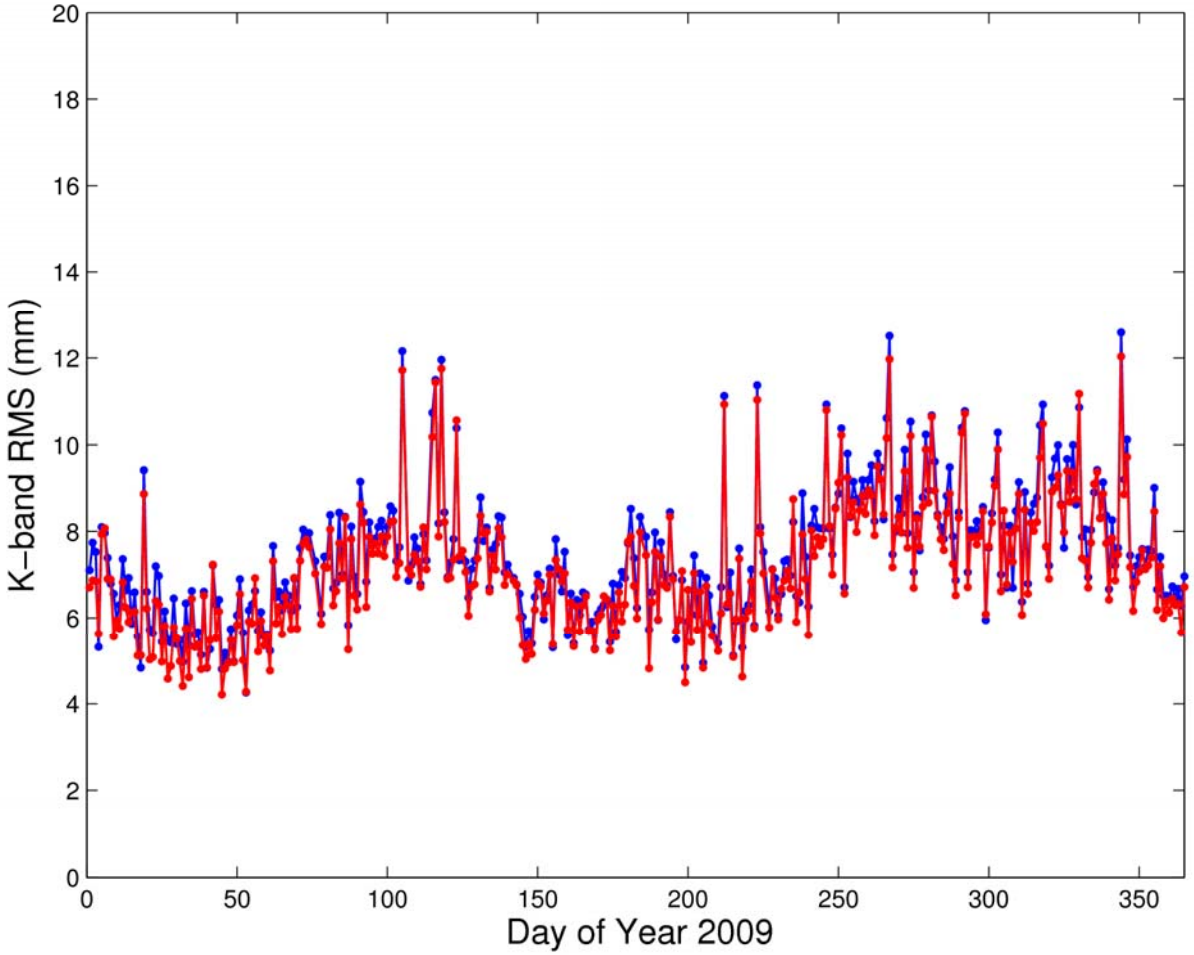
Jason-2



GOCE

Impact on LEO POD

GRACE K-band validation



PCVs used:

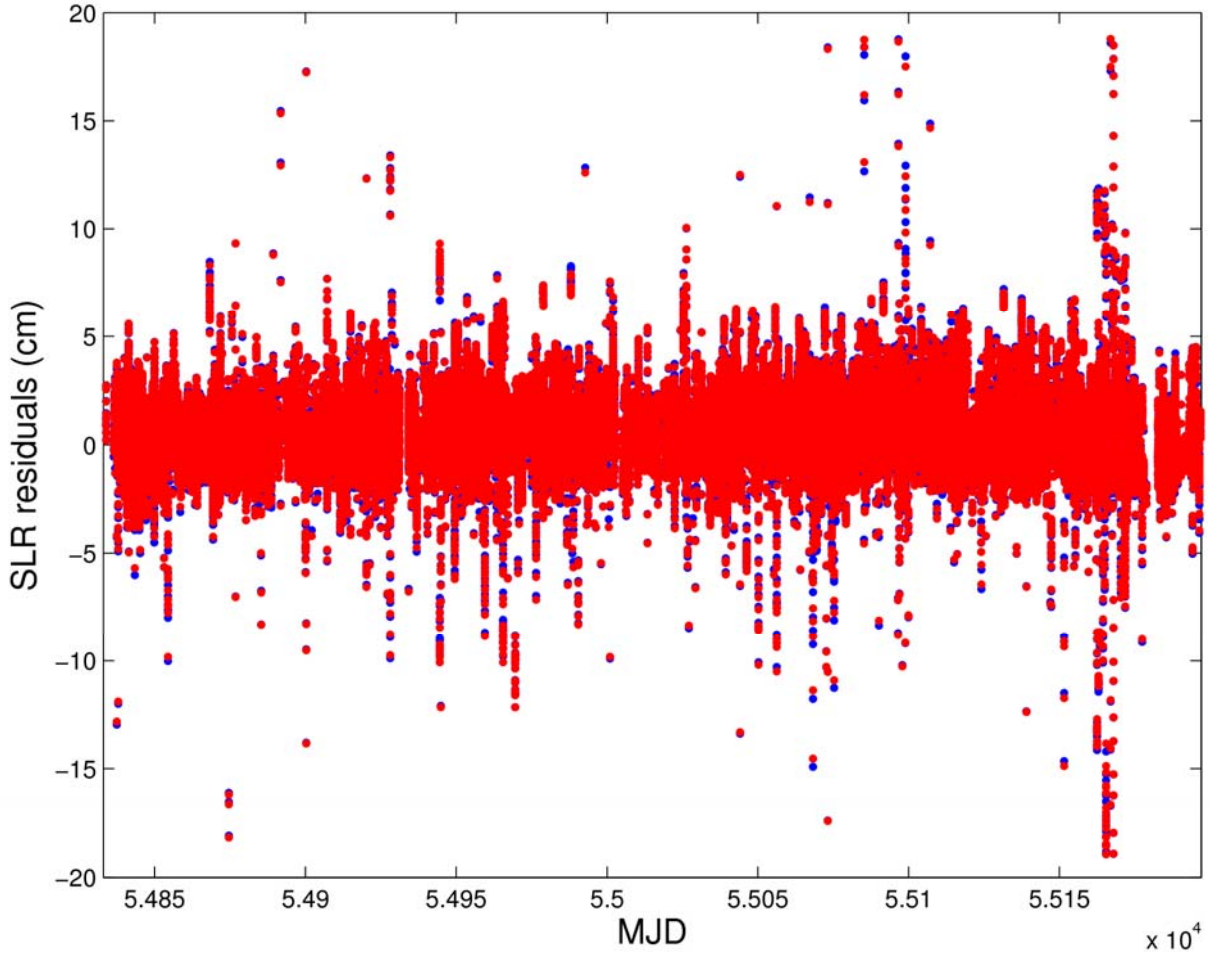
GRACE & igs08

GRACE & extended

Small improvement from 7.4 to 7.1 mm K-band range STD

Impact on LEO POD

GRACE SLR validation



PCVs used:

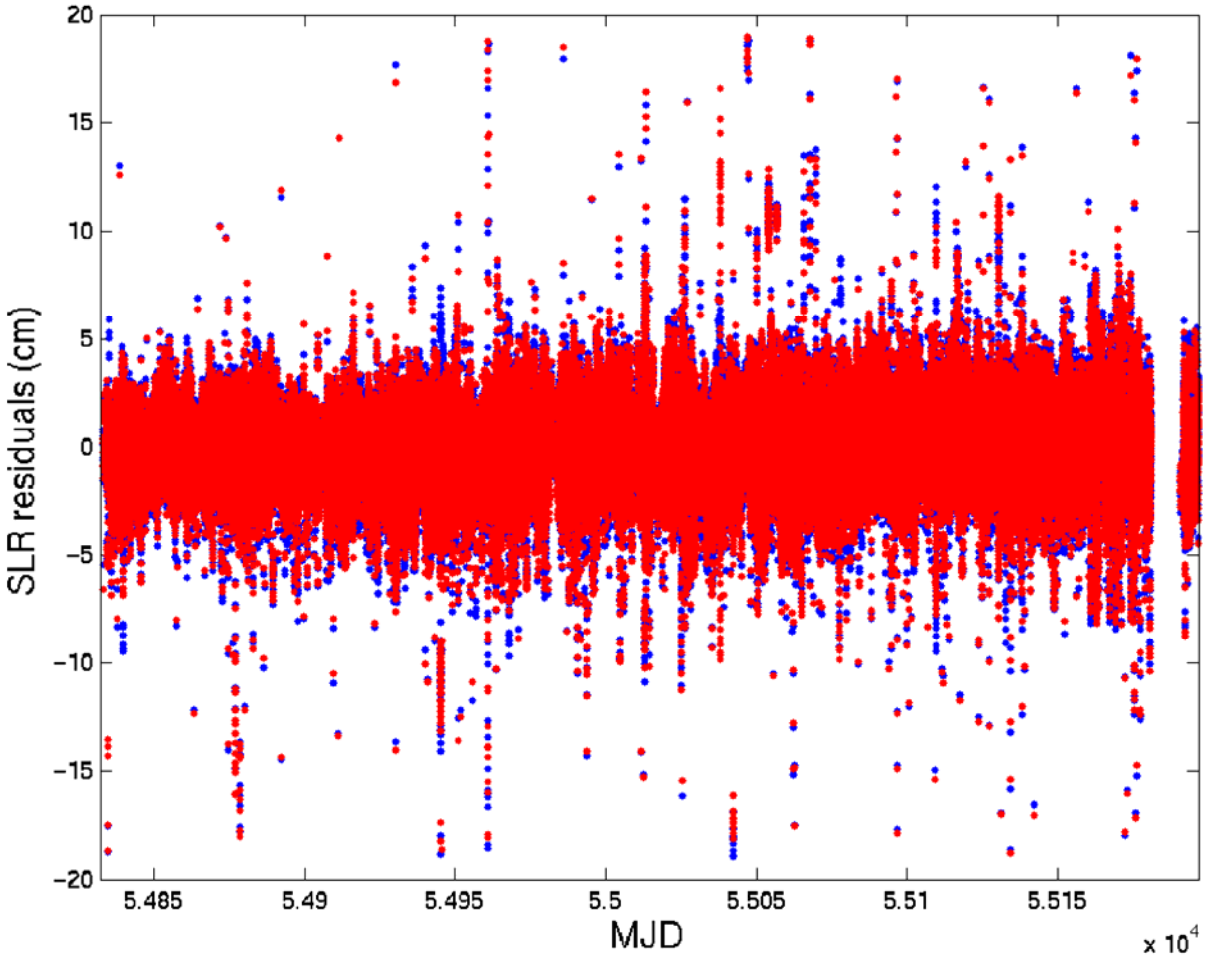
GRACE & igs08

GRACE & extended

Almost no improvement from 1.85 cm to 1.84 cm SLR RMS

Impact on LEO POD

Jason-2 SLR validation



PCVs used:

Jason-2 & igs08

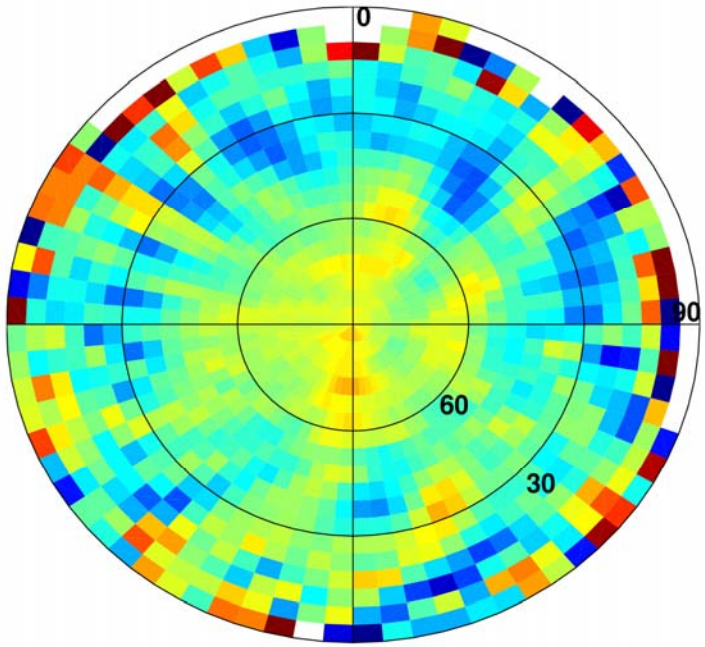
Jason-2 & extended

Small improvement from 1.77 cm to 1.71 cm SLR RMS

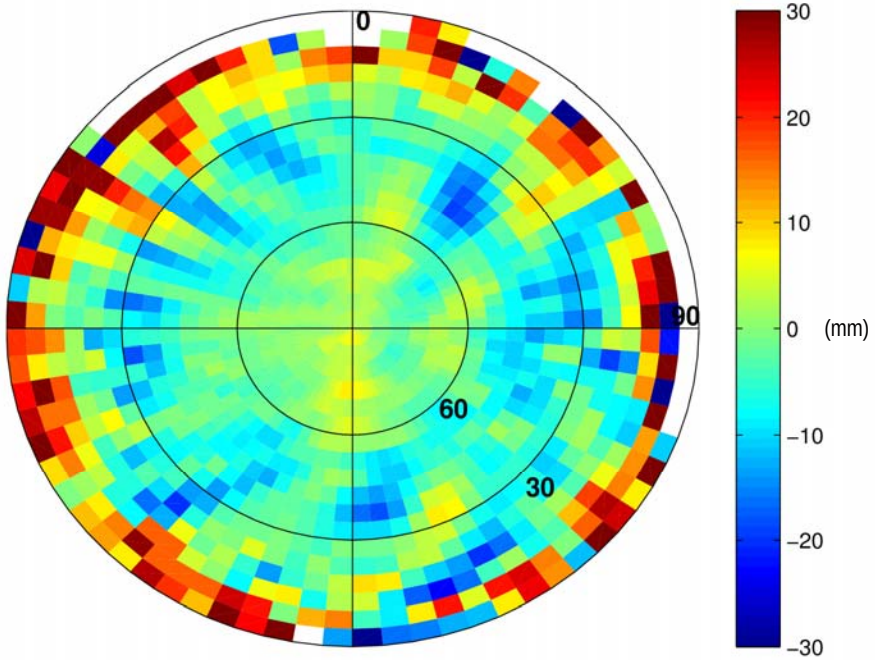
Impact on LEO POD

Why only such a small impact?

LEO PCVs (extended GPS PCVs)



LEO PCVs (mismodeled GPS PCVs)



LEO PCVs may absorb systematic effects at low elevations to a large extent ==> orbit solutions of good quality may still be obtained, even if GPS PCVs are not properly modeled by an extension beyond 14°

Conclusions

- Satellite-specific GPS PCVs were simultaneously estimated with LEO PCVs from pure LEO GPS data
- Constraints are required to enable the simultaneous estimation of GPS and LEO PCVs when using only LEO GPS data
- Simultaneous PCV estimation is required to avoid mapping of mismodeled LEO PCVs into the GPS PCVs
- Satellite-specific GPS PCVs may be consistently estimated wrt igs08.atx, the agreement is about 2-3 mm below 14°
- Satellite-specific GPS PCVs show a good agreement of about 1 mm with estimates from terrestrial data
- Block-specific values show an excellent agreement of better than 1 mm with estimates from terrestrial data
- Block-specific values could be used to consistently extend igs08.atx PCVs beyond 14°

Recommendation to the IGS