

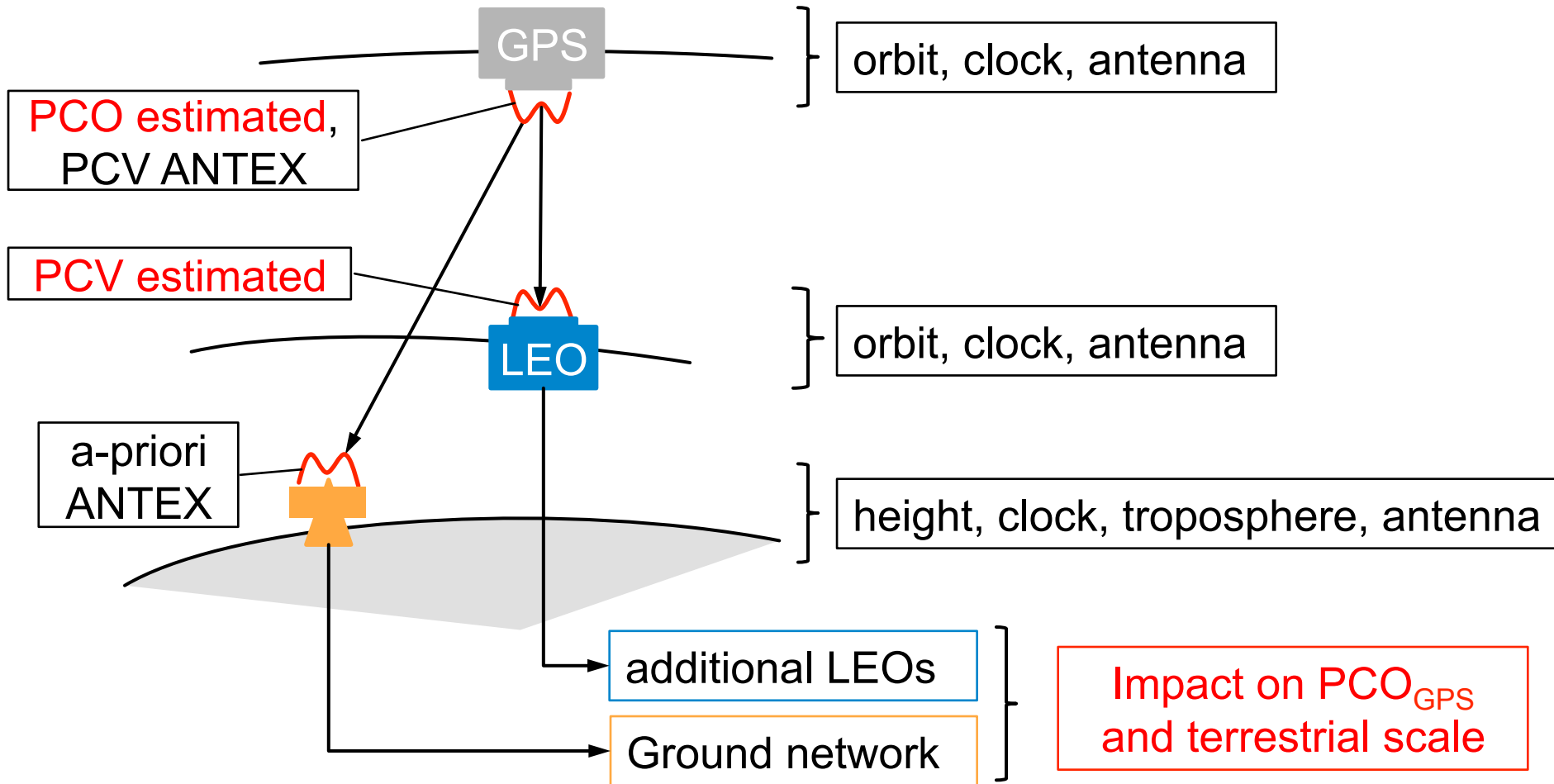
Satellite Antenna Phase Center Offsets and the Terrestrial Scale

in a Combined Processing of LEO and Ground-based GPS

B. Männel and M. Rothacher, ETH Zürich

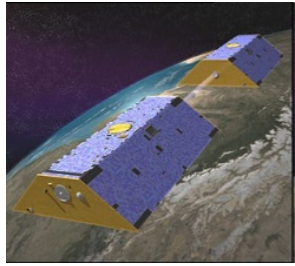


Phase center offset and terrestrial scale



Database (2010 – 2012)

GRACE
450 km / 89°



GOCE
240 km / 96°



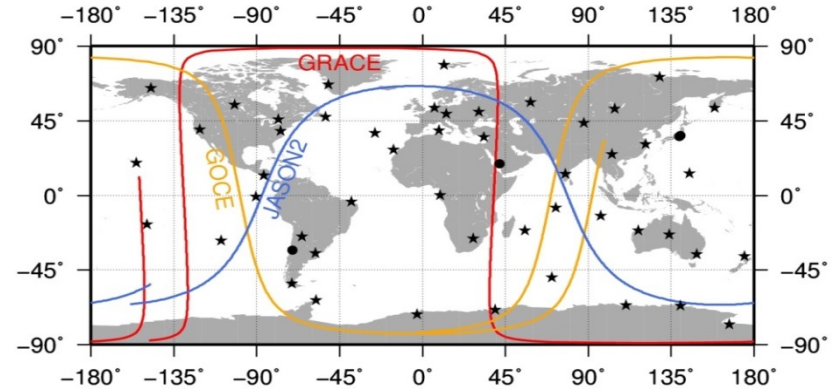
OSTM/Jason-2
1336 km / 66°



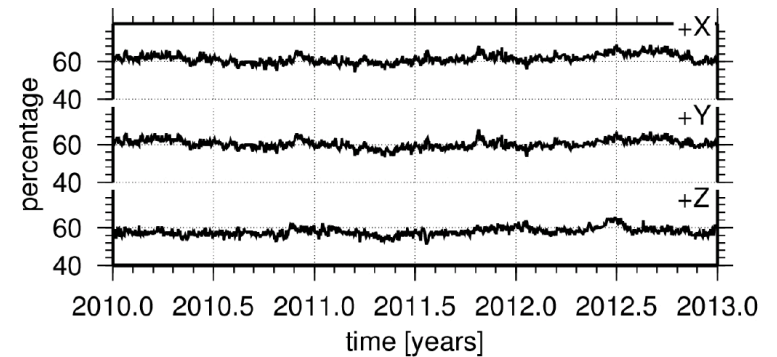
data rate 10s, 3° elevation cut-off

Comp.	LEO	radial	along	cross	3D	ref
	GRACE-A	1.41	1.98	1.28	2.74	JPL ^a
GRACE-B	1.43	1.91	1.14	2.64	JPL ^a	
GOCE	1.96	2.54	2.68	4.18	ESA ^b	
Jason-2	1.77	3.66	1.80	4.44	ESOC ^c	

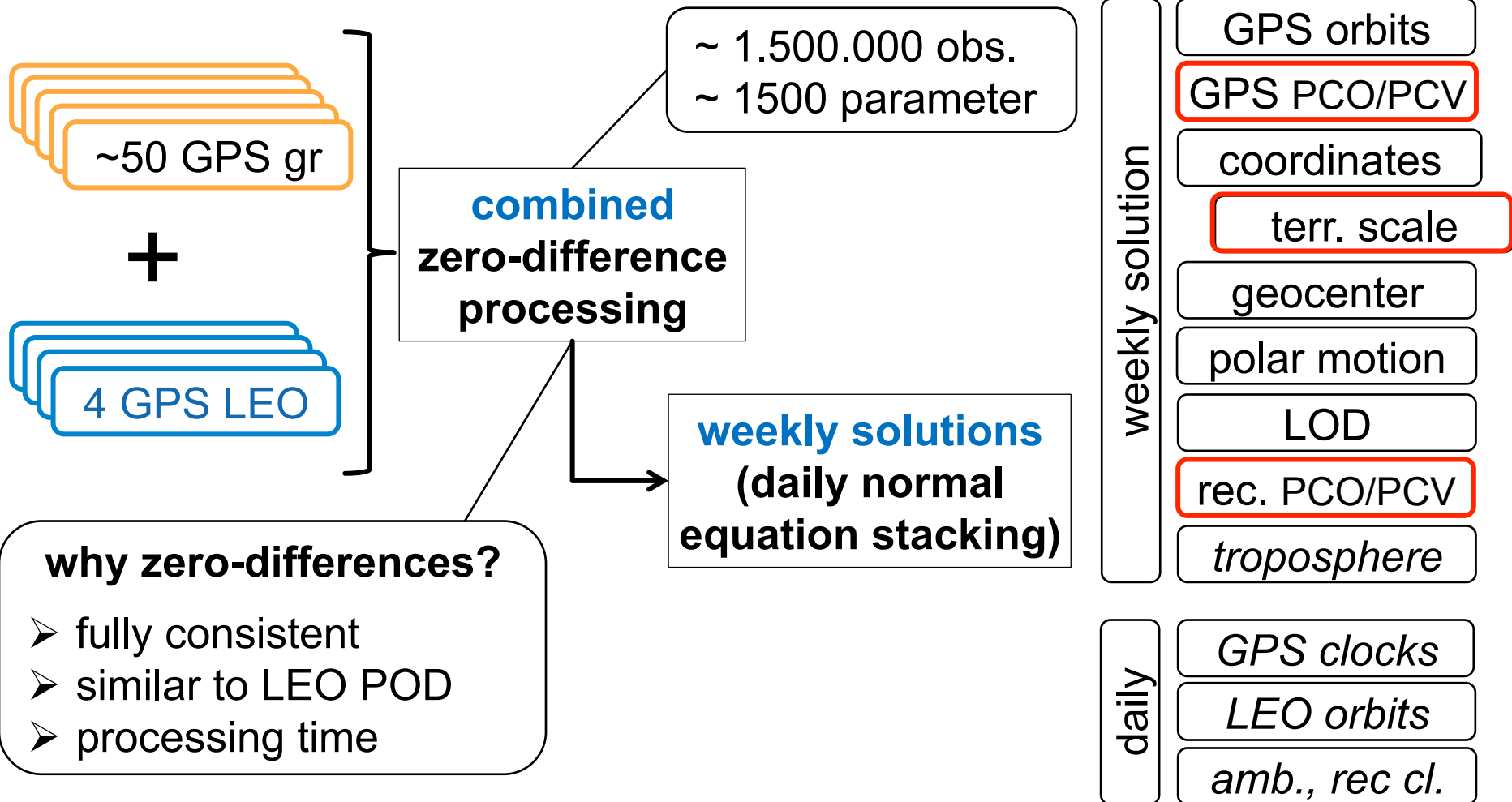
SLR		GRACE-A	GRACE-B	GOCE	Jason-2
	# obs		59'565	60'870	17'939
mean [cm]		-0.27	-0.35	-2.10	-0.07
RMS [cm]		2.69	2.70	3.68	2.88



data rate 30s, 3° elevation cut-off



Combined LEO- and ground based GPS



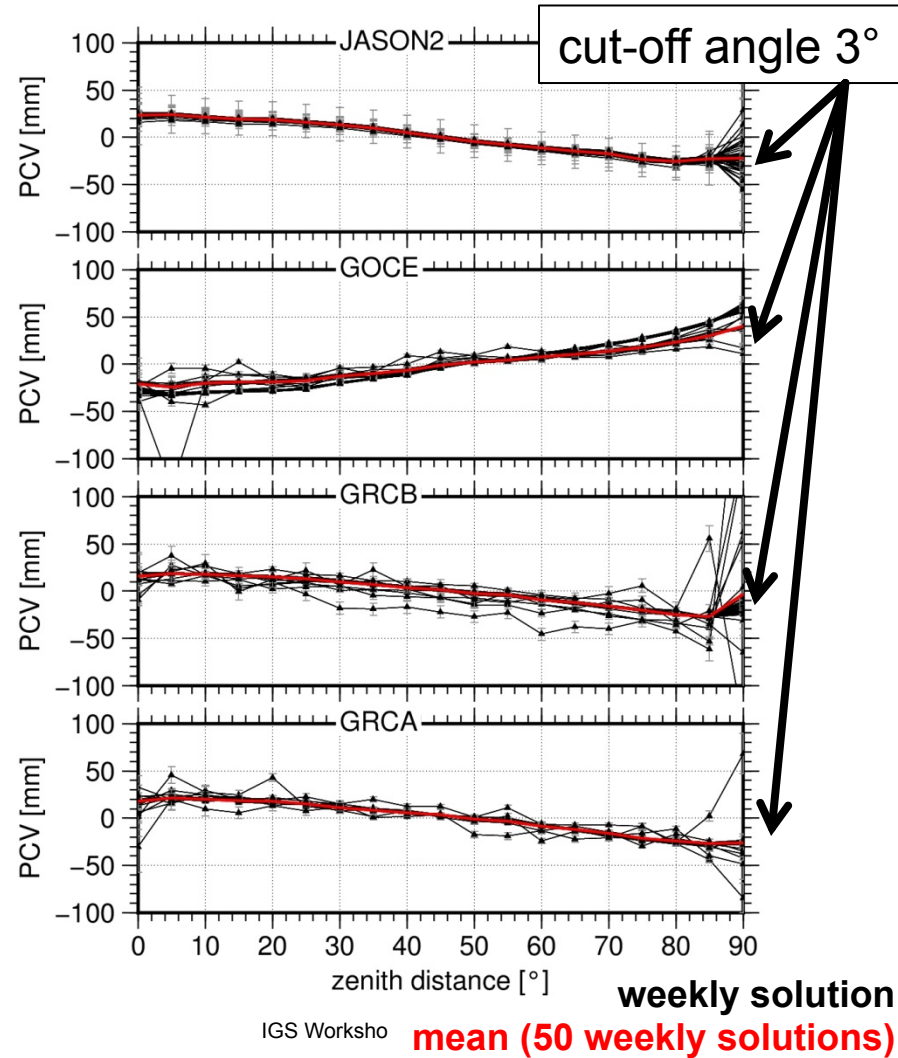
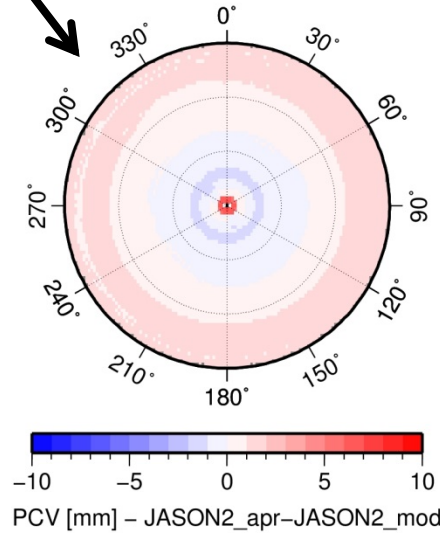
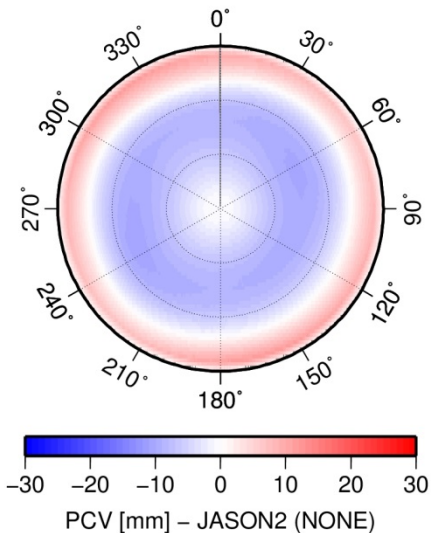
LEO antenna phase center variations

- a priori estimation
→ setup LEO orbit + PCV
- elevation-depending pattern

$$\Delta PCV = PCV_{\downarrow 2} - PCV_{\downarrow 1} + PCO_{\downarrow 2} \cos(z) - PCO_{\downarrow 1} \cos(z) + \Delta offset$$

robot calibration

difference



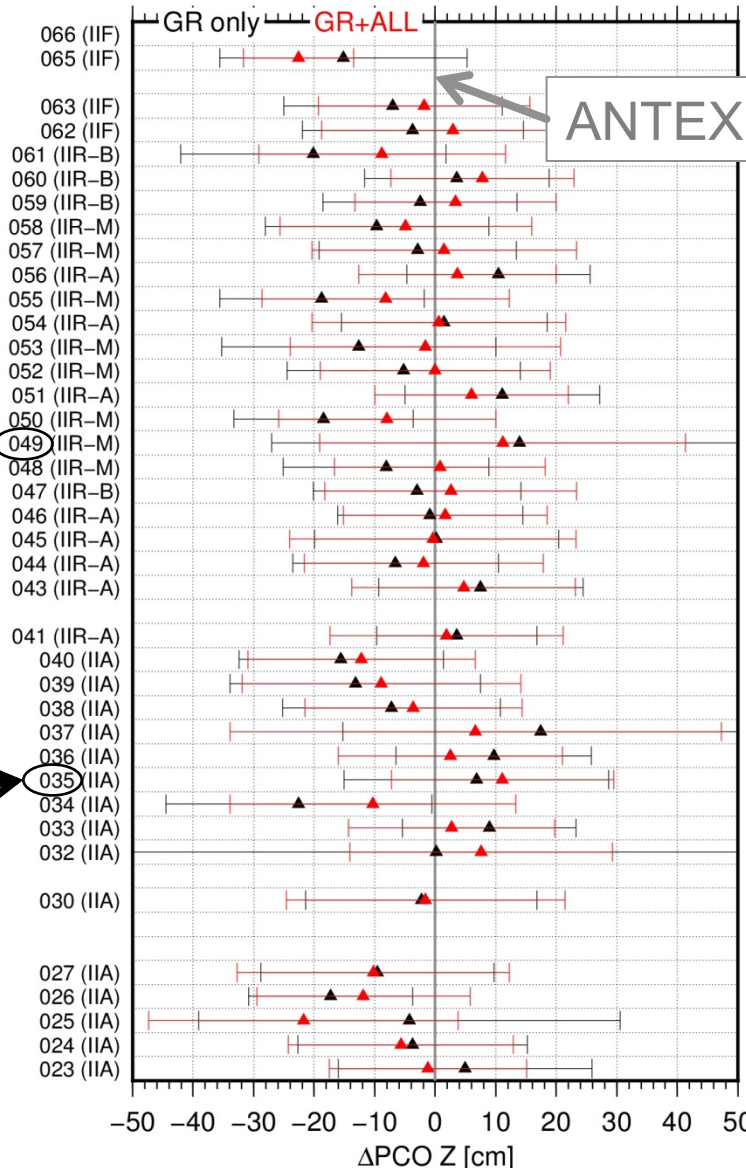
Z-PCO_{GPS}: mean correction (LEO combination)

GR: ground only estimation

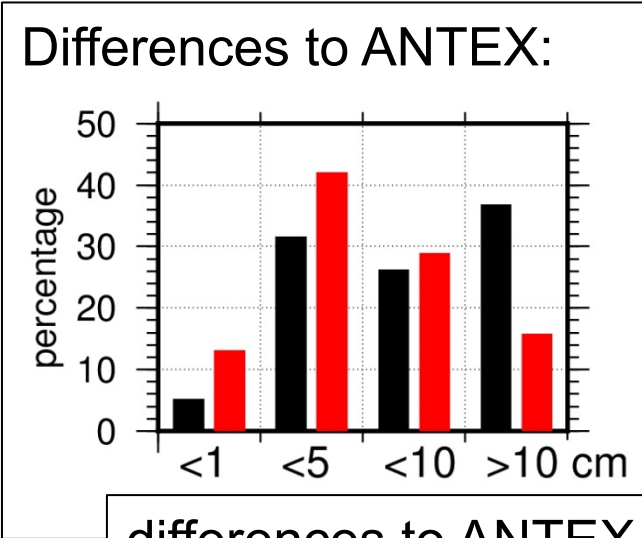
GR+ALL: ground + 4LEO combination

“experimental” SVN 049

recommissioned SVN 035



* only short time series available



differences to ANTEX are smaller for the combined solution

Z-PCO_{GPS}: mean correction (individual LEOs)

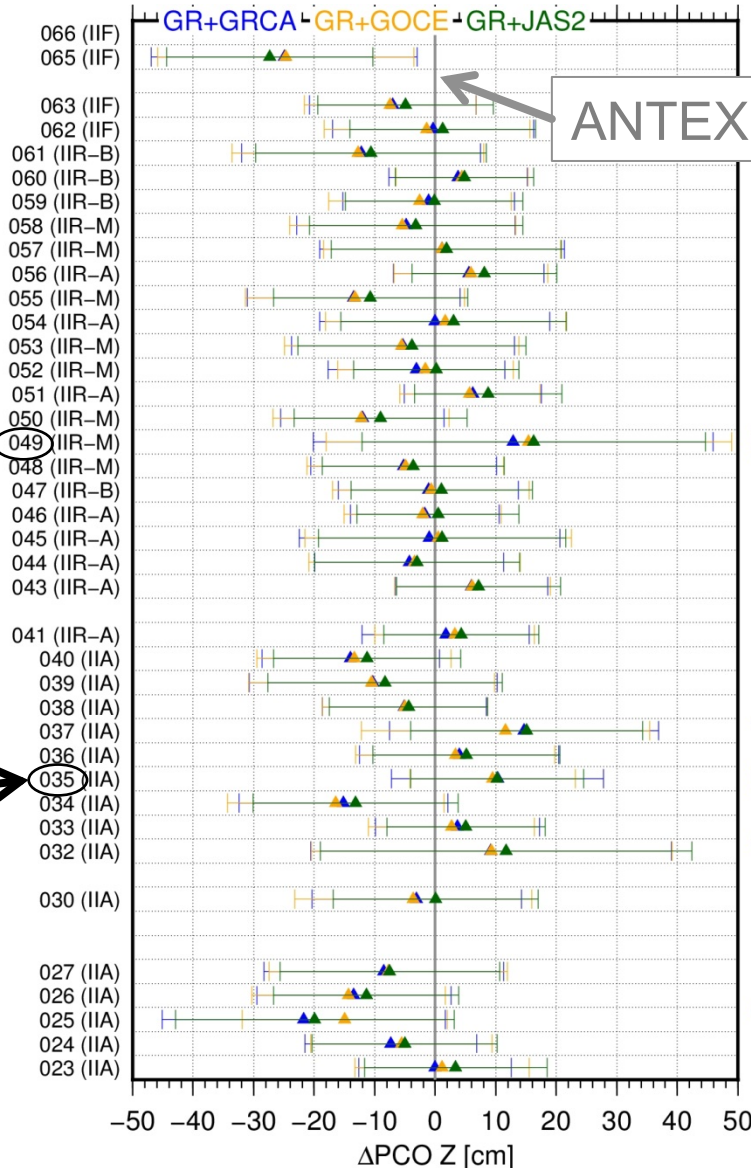
GR+GRACE-A

GR+GOCE

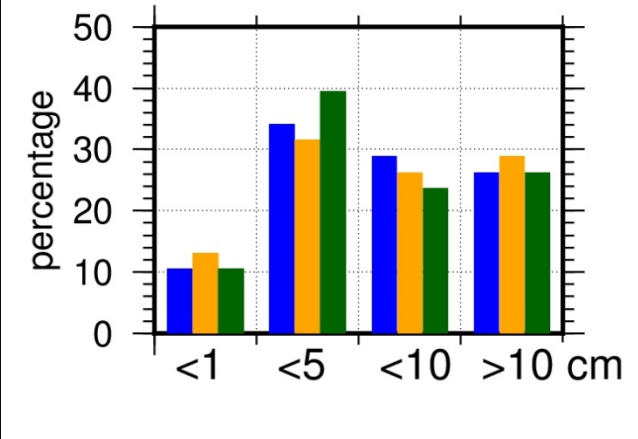
GR+OSTM/
Jason-2

“experimental”
SVN 049

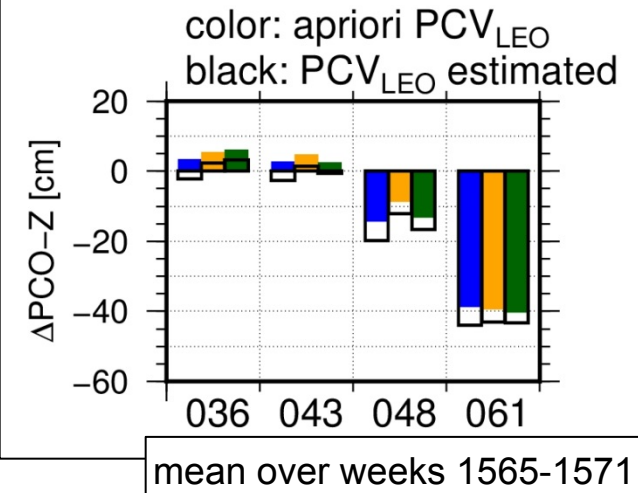
recommissioned
SVN 035



Differences to ANTEX:



PCV_{LEO} estimation:



Z-PCO_{GPS}: time series

the individual LEO solutions are very similar

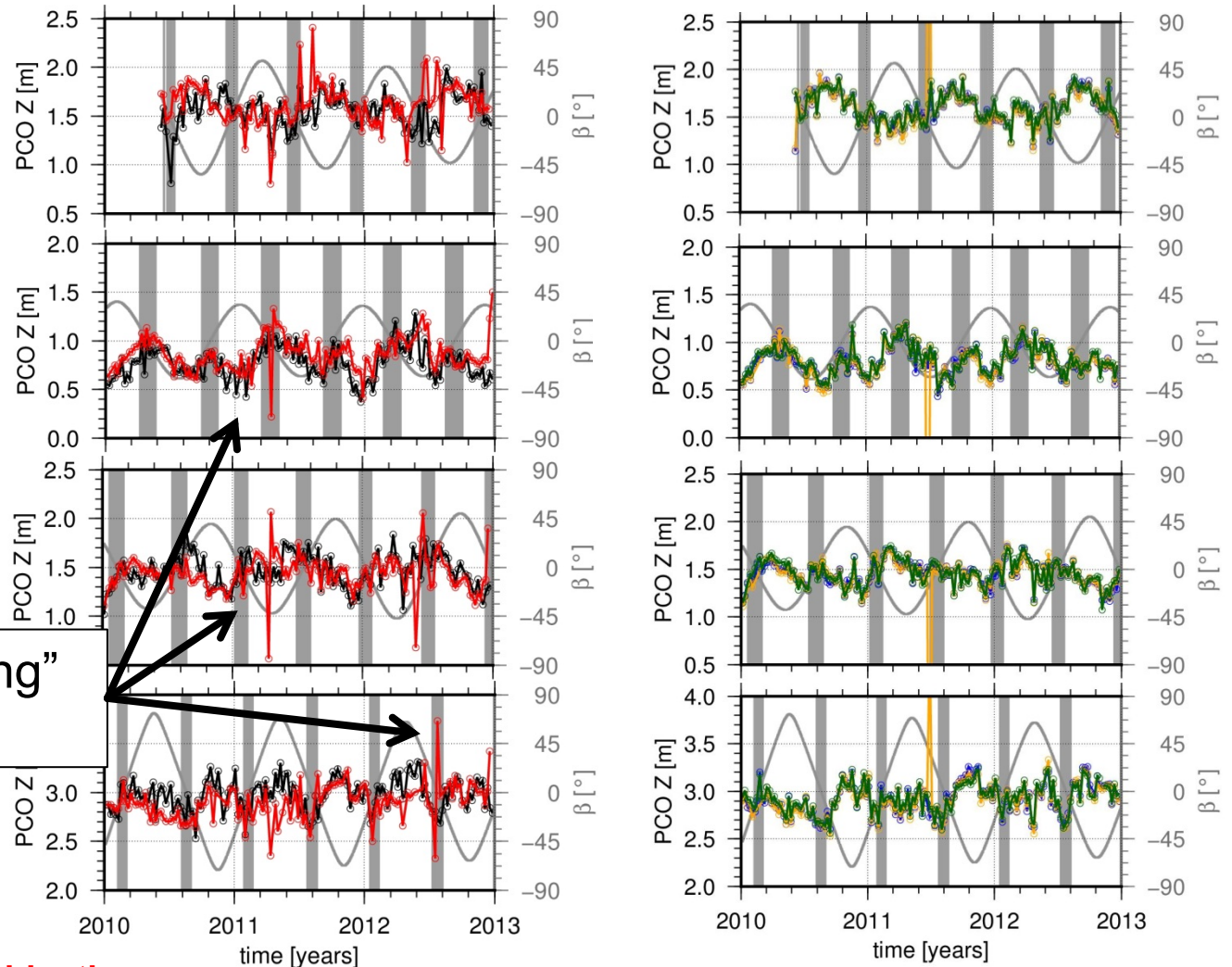
SVN 062 (IIF)

SVN 048 (IIR-M)

SVN 043 (IIR-A)

reason for “misbehaving” weeks so far unknown

SVN 036 (IIA)



GR: ground only estimation

GR+ALL: ground + 4LEO combination

GR+GRACE-A GR+GOCE GR+OSTM/Jason-2

X-PCO_{GPS} and Y-PCO_{GPS}

improvement due to additional LEOs during periods with large β angles

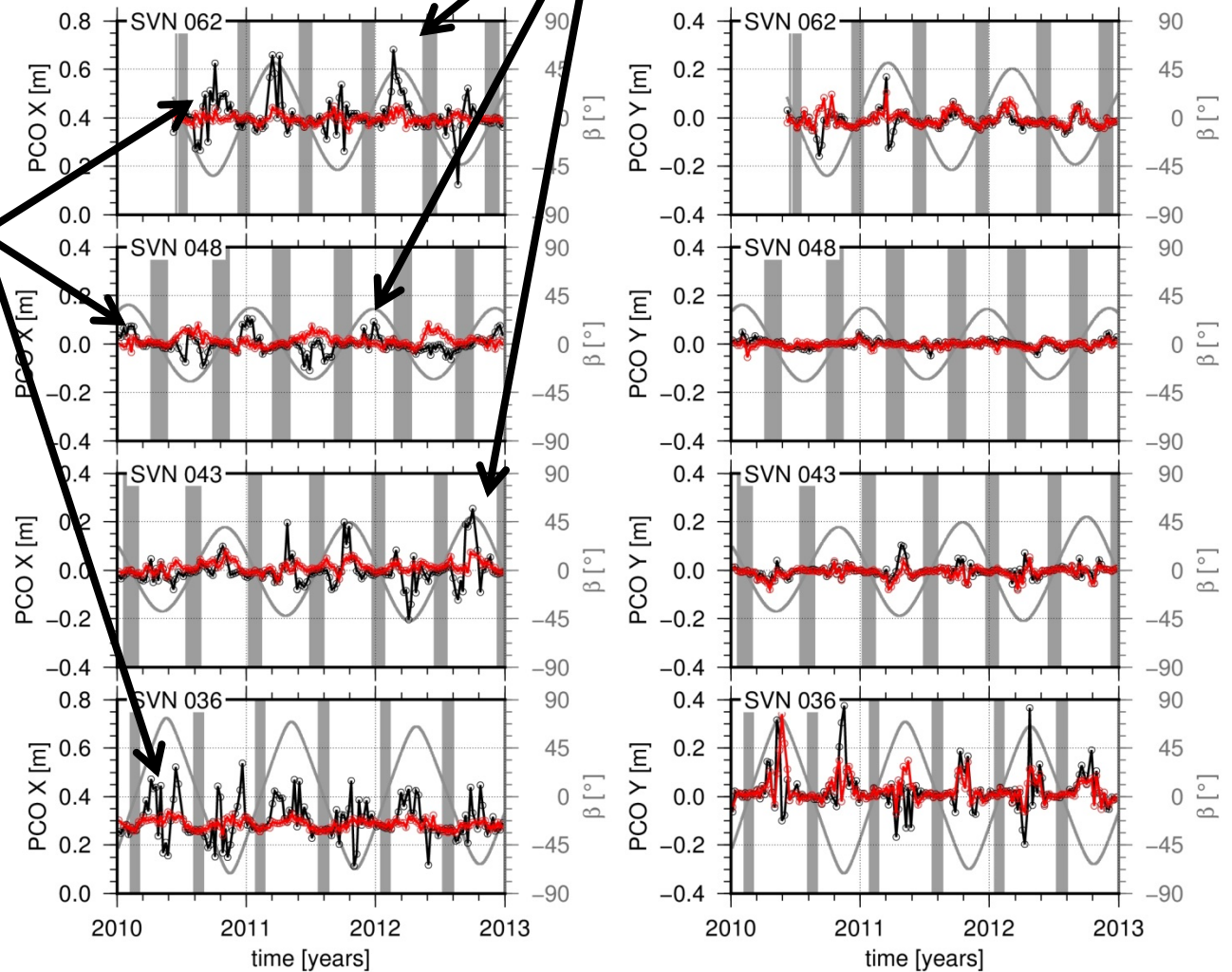
SVN 062 (IIF)

weak determination for large β angles

SVN 048 (IIR-M)

SVN 043 (IIR-A)

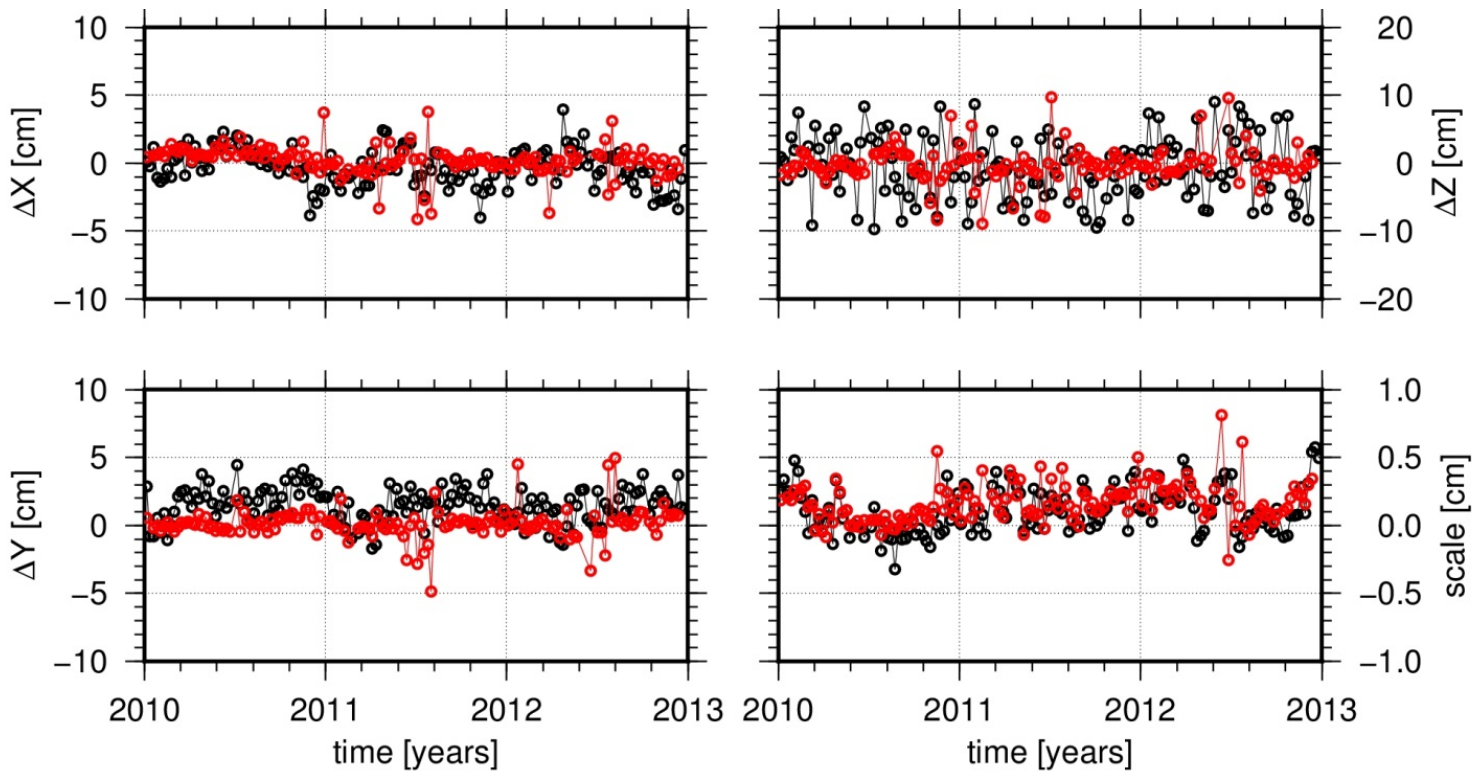
SVN 036 (IIA)



GR: ground only estimation
 GR+ALL: ground + 4LEO combination

Coordinate Solution compared to ITRF2008

- weekly combination; parameters included orbits, coordinates, ERPs
- NNR (subset of stable station)



GR: ground only estimation

GR+ALL: ground + 4LEO combination

Coordinate Solution compared to ITRF2008

	PCO _{GPS} ANTEX		PCO _{GPS} ETHZ		Haines et al, 2015			
ΔX								
amp.	8.9±0.2	1.7±0.2	1.7±0.1	0.8	1.9±0.6	6.5±0.5	9.8±0.4	1.3
trend	-8.0±0.5	1.1±0.6	1.0±0.5	0.3	-28.6±2.1	-6.7±1.4	-2.1±1.5	0.03
RMS	13.5	11.1	11.2	4.6	46.4	26.9	28.8	4.7
ΔZ								
amp.					1.3±0.02	0.8±0.02	1.0±0.01	1.0
trend					1.3±0.07	0.8±0.07	0.9±0.06	0.3
RMS					1.7	1.5	1.3	1.7
ΔY								
amp.	2.9±0.2	4.3±0.2	4.6±0.2	3.6				
trend	12.7±0.5	-1.3±0.5	-2.6±0.5	-0.3				
RMS	1.26	11.1	10.6	5.1				
scale								
amp.					1.3±0.02	0.8±0.02	1.0±0.01	1.0
trend					1.3±0.07	0.8±0.07	0.9±0.06	0.3
RMS					1.7	1.5	1.3	1.7

annual amplitude [mm]. trend [mm/yr], RMS[mm]

GR: ground only estimation

GR+ALL: ground + 4LEO combination (ANTEX)

GR+ALL: ground + 4LEO combination (ETHZ)

Good agreement in translation (X, Y) and scale to Haines et al., 2015

Conclusions and next steps

- combined processing of ground network and up to four LEOs (GRACE-A, GRACE-B, GOCE, OSTM/Jason-2)
- estimation of PCO_{GPS}
 - good agreement to ANTEX values: 60% <5cm; 85% <10cm
 - PCO from individual LEOs are similar (differences ~5cm)
 - significant improvement in X- and Y- PCO_{GPS} in periods with large β - angle
- estimation of transformation parameters w.r.t. ITRF2008
 - large improvement in translation due to LEOs
 - small improvement in scale due to LEOs
 - results from combined solution close to results by Haines et al., 2015

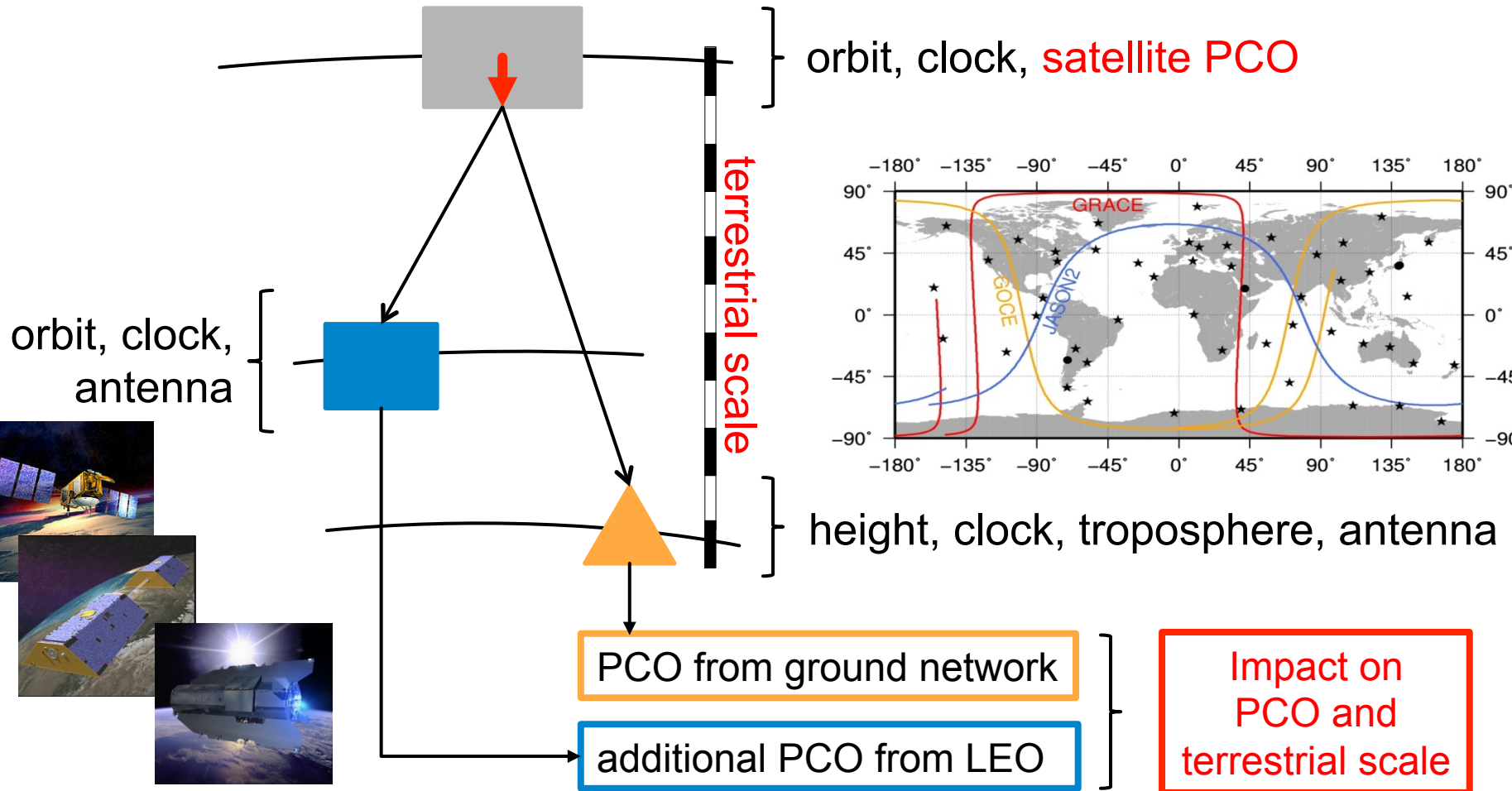
Thank you for your kind attention

Contact: maennelb@ethz.ch

This work was done within DFG-Project "**Space-Time Reference Systems**" (FOR 1503)



Phase Center Offset and terrestrial Scale



X-PCO_{GPS} and Y-PCO_{GPS}

ground+LEO: weekly solutions more noisier

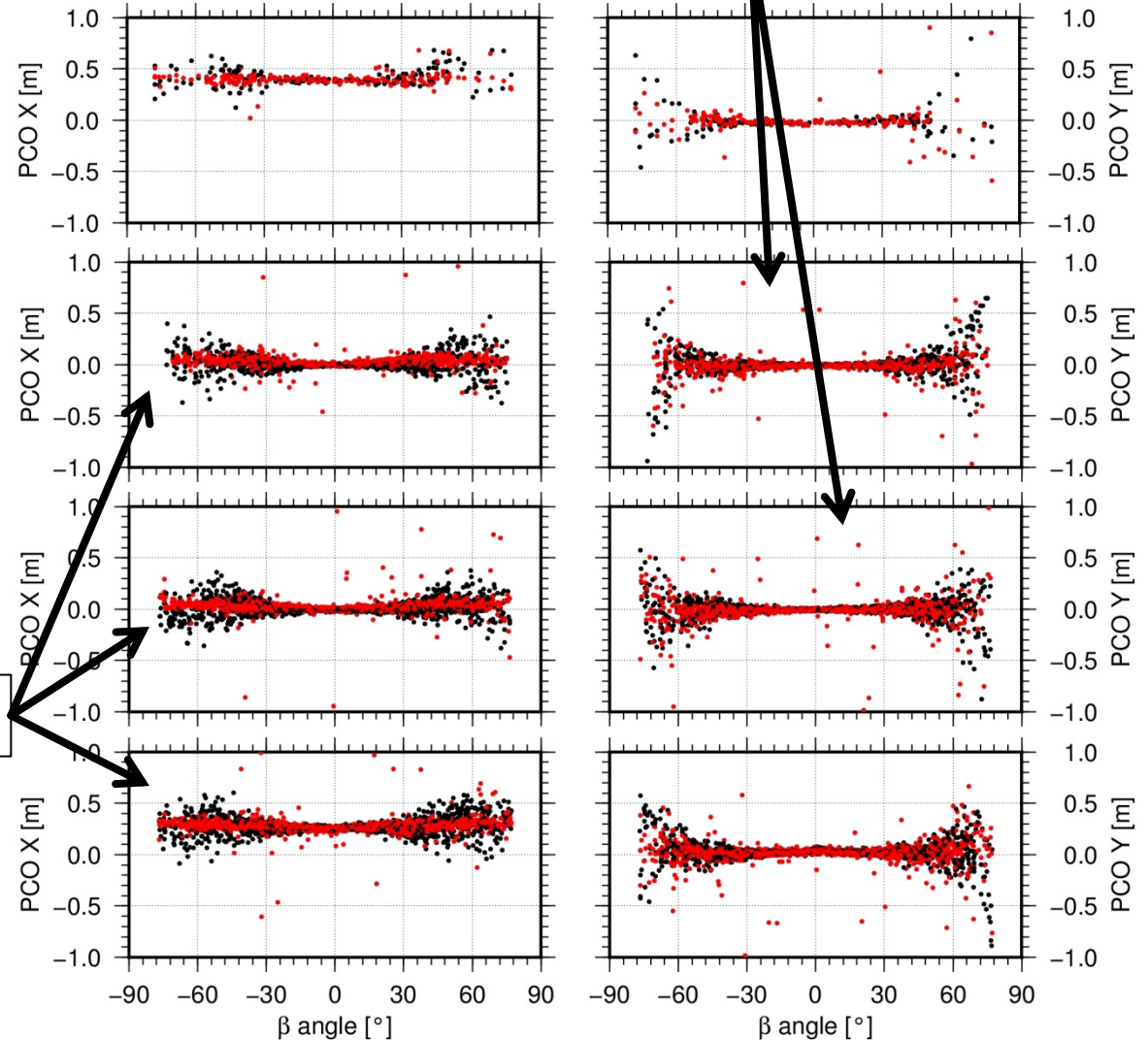
Block IIF

Block IIR-M

Block IIR-A

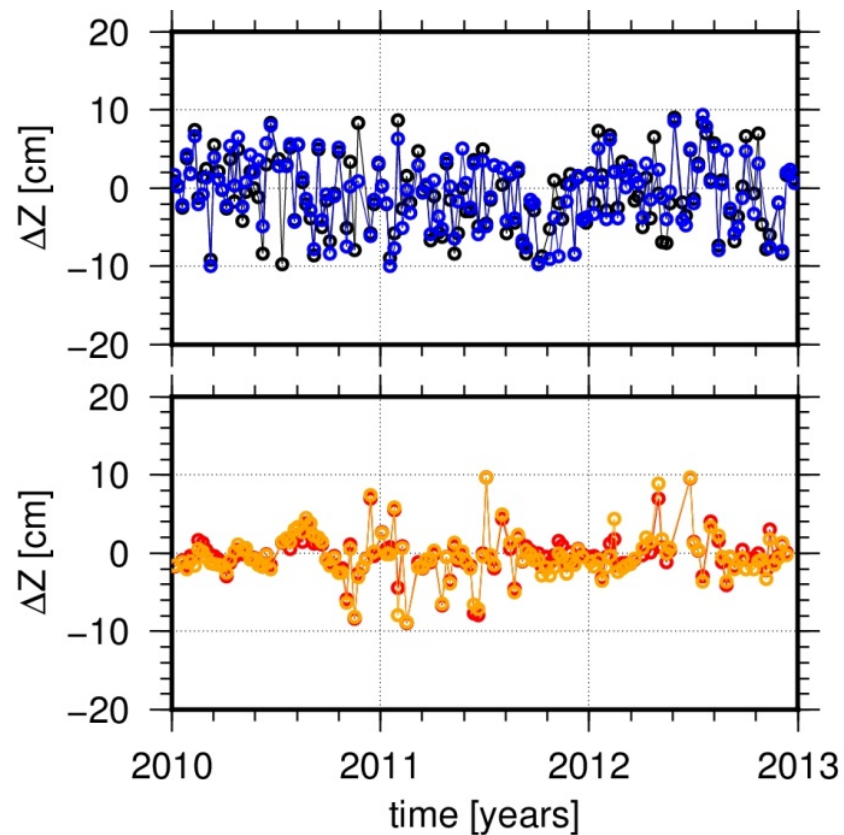
Block IIA

improvement in X-PCO_{GPS}



Difference in Z-translation

ground (ANTEX PCO_{GPS})
ground (ETHZ PCO_{GPS})
ground+LEOs (ANTEX PCO_{GPS})
ground+LEOs (ETHZ PCO_{GPS})



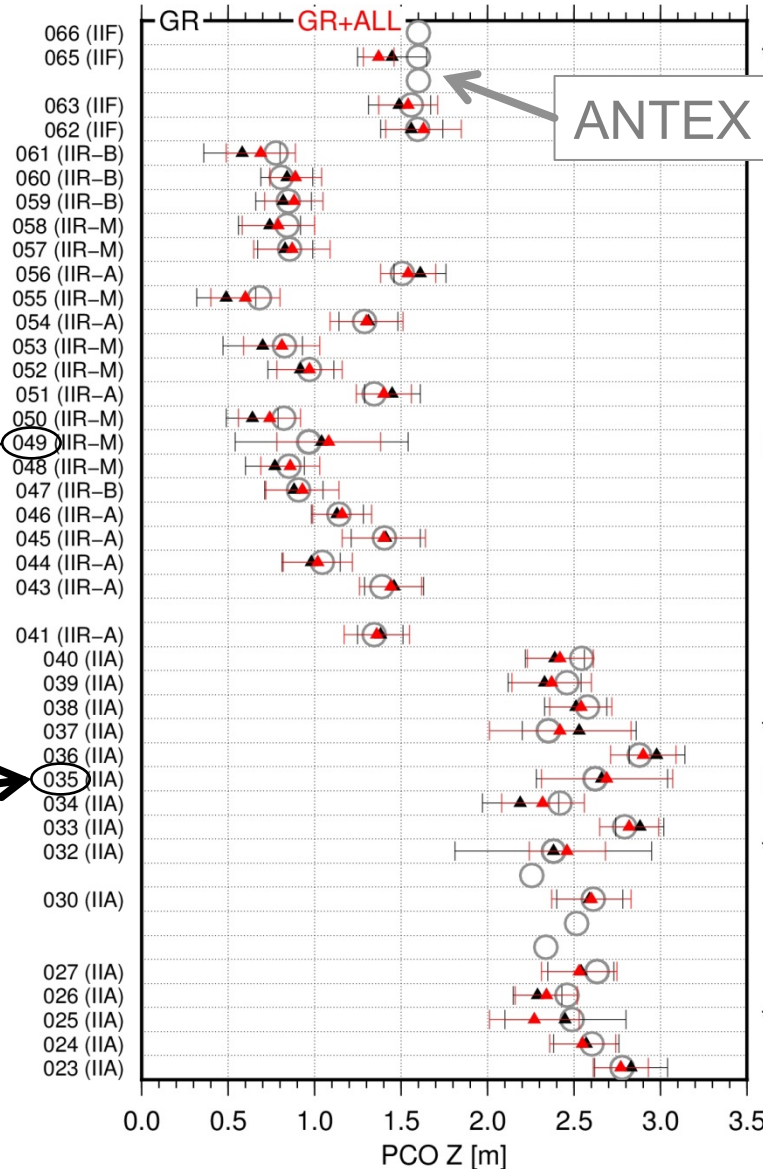
Z-PCO_{GPS}: mean values (LEO combination)

GR: ground only estimation

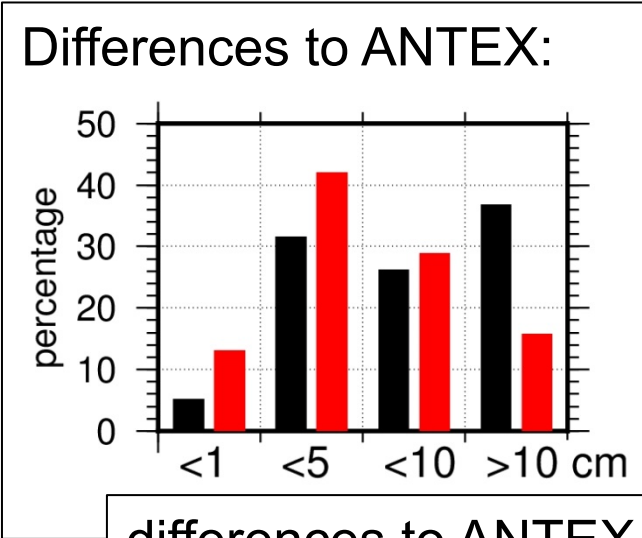
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Z-PCO_{GPS}: mean values (individual LEOs)

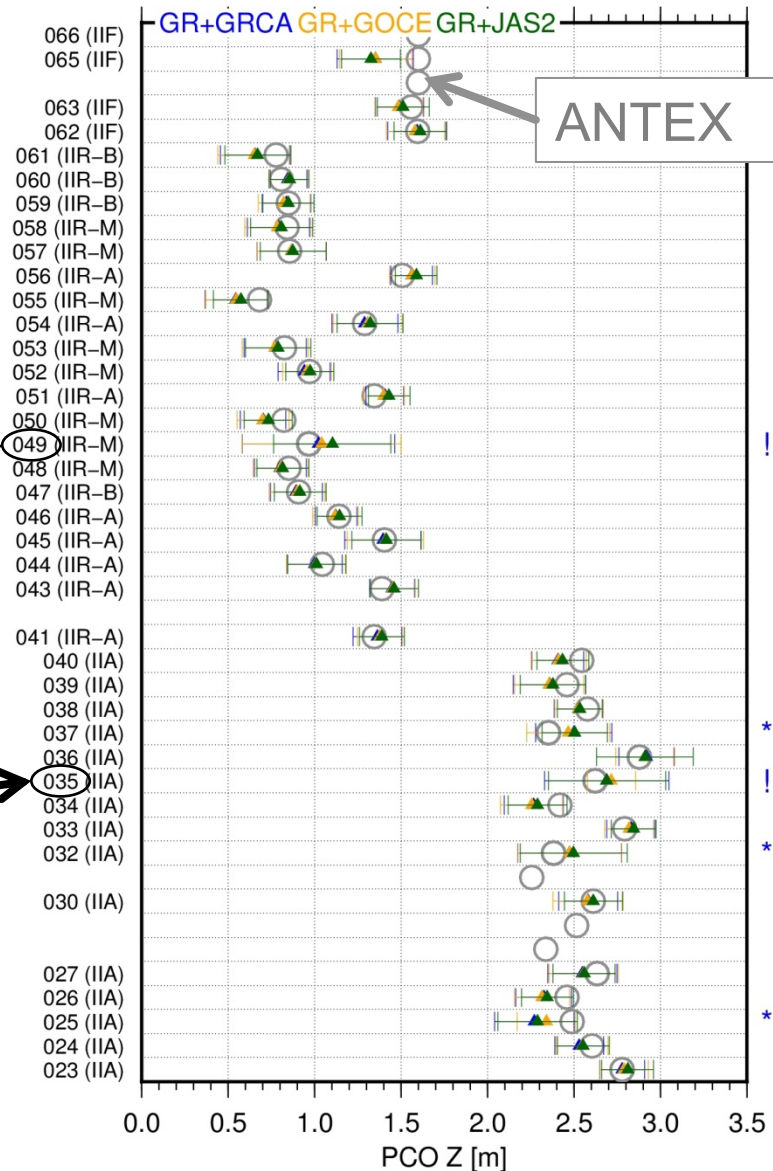
GR+GRACE-A

GR+GOCE

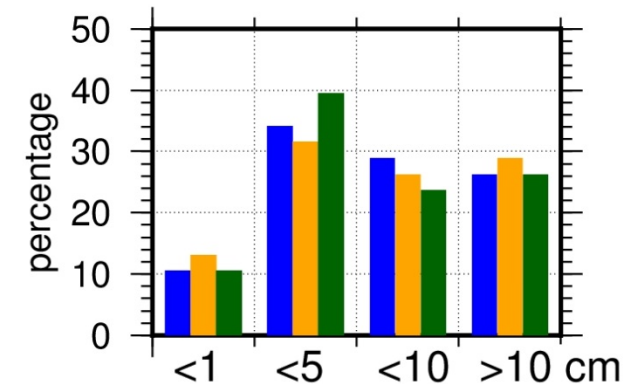
GR+OSTM/
Jason-2

“experimental”
SVN 049

recommissioned
SVN 035



Differences to ANTEX:



PCV_{LEO} estimation:

