GGOS Unified Analysis Workshop

Session 2
Technique-Specific Biases and Effects at Co-Location Sites/Satellites

Identification of Systematics by Co-location on Satellite

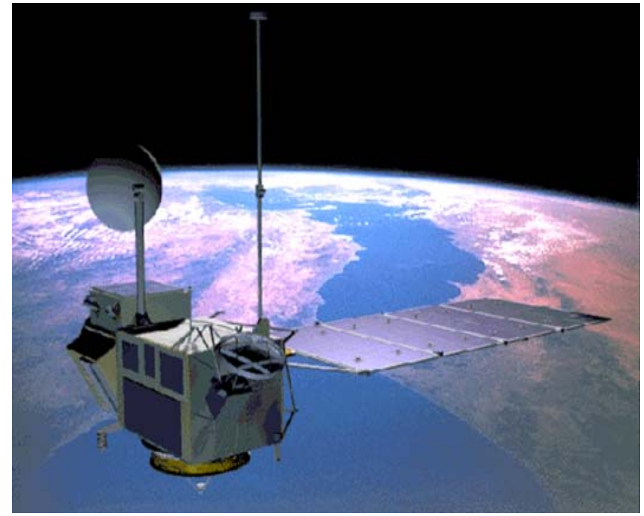
December, 5-7 2007

Monterey, California, USA

Examples and Benefits of Co-location on Satellite

- Confidence in orbit accuracy assessment by intercomparison with independent techniques

TOPEX/POSEIDON



Comparison of SLR/DORIS and GPS-based orbits (JGM-3, 1996)

SLR/DORIS ORBITS COMPARED TO JPL REDUCED DYNAMICS

T/P Cycle	Radial RMS	Transverse RMS	Normal RMS	Mean Z
43 *	1.8	6.0	9.2	-1.5
44	1.7	6.5	9.5	-0.4
45	1.5	5.9	9.3	0.2
46 *	1.9	6.8	8.9	-0.2
47 *	1.6	6.1	9.4	-2.1
48	1.8	5.9	8.8	1.4
49	1.6	5.6	8.8	-2.3
50	1.6	5.6	7.2	-2.4
mean	1.7	6.1	8.9	-0.9

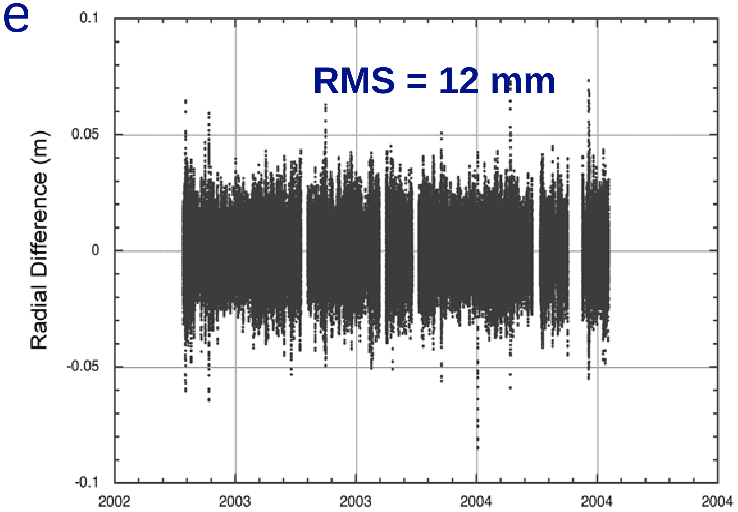
Notes:
1) all units cm
2) radial rms is calculated with z-bias removed; however, no RMS exceeded 2 cm with z-bias left in
3) cycles with yaw ramps/flips (*) are more difficult
3) JGM-3 gravity and improved tide models used throughout

- 5-6 cm mean radial orbit difference between early GPS and SLR-based orbits could be identified as an inconsistency in the GPS orbits
- Mean radial differences between dynamic and reduced-dynamic orbits could be attributed to residual errors in JGM-1 gravity model $\Rightarrow$ JGM-3
- 7-10 microsec apparent time bias in DORIS data observed…led to examining time tagging for other DORIS satellites
- GPS and SLR supported precision altimeter calibration sites

Examples and Benefits of Co-location on Satellite

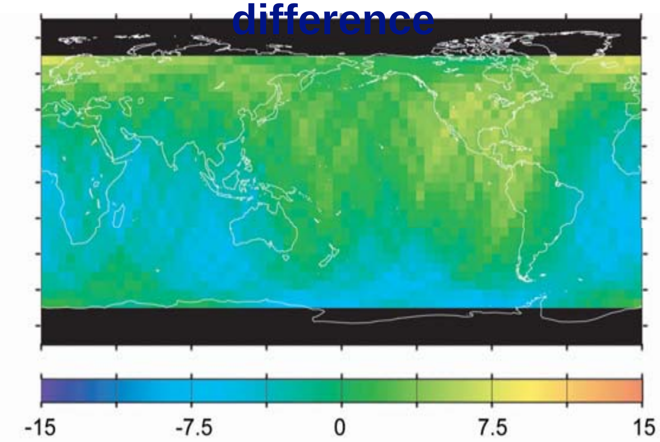
- Confidence in orbit accuracy assessment by intercomparison with independe

Comparison of SLR/DORIS and GPS-based orbits (GGM01S, 2004)



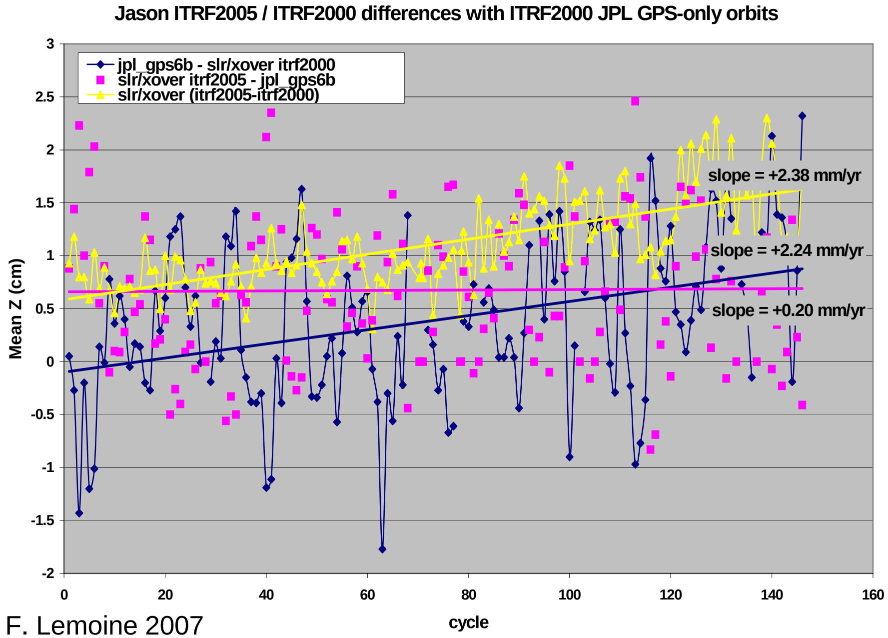
Jason-1

Mean radial orbit difference



- Mean radial differences between dynamic and reduced-dynamic orbits could be attributed to residual gravity model errors in GGM01S
- DORIS time bias monitored with SLR (& GPS
- GPS and SLR supported precision altimeter calibration sites

Co-location Reveals Systematics in Jason-1 Models

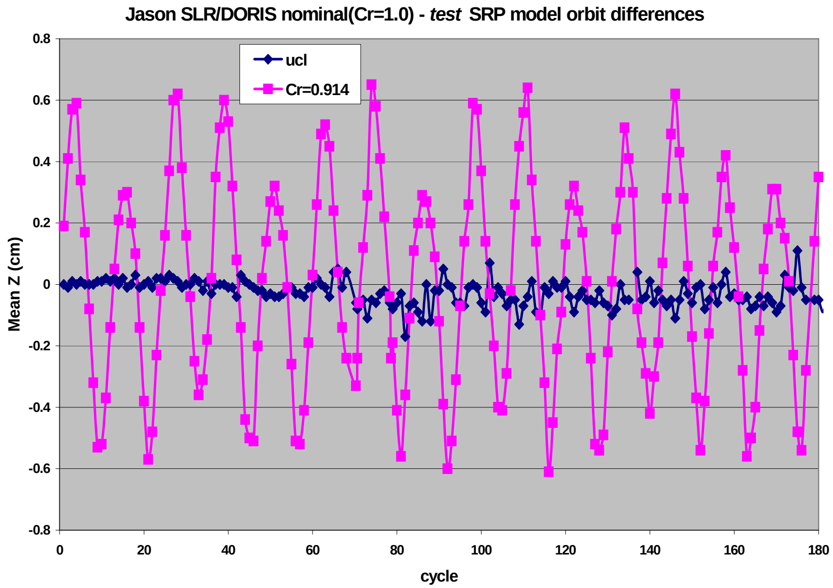


F. Lemoine 2007

Differences between SLR/XOVER (dynamic) and GPS (reduced-dynamic) orbits revealed significant systematic variation in mean Z orbit component (at beta-prime frequency)

Futher analysis indicated that solar radiation pressure model error causes Z-bias in orbit centering

Could have important implications for sun-synchronous orbits (SPOT, ENVISAT)



F. Lemoine 2007

Co-location led to On-orbit Updates to Jason-1 CoM

Common correction to antenna phase center seen in multiple techniques could be confidently assigned to CoM error

Correction unique to one technique suggested alternative source of bias

Nominal	X (mm)	Y (mm)	Z (mm)	
GPS LC	1447	-218	-504	
SLR	229	598	683	
DORIS	229	-598	1027	
	Delta-X	Delta-Y	Delta-Z sinusoidal yaw	Delta-Z fixed yaw
JPL GPS	-15		-43	
CSR GPS	-13		-34	
NASA GPS	-15	2	-40	-60
GPS average	-14		-39	
NASA SLR	-13		3	
NASA DORIS	-10	6	-22	
JPL/IGN DORIS	-17	5	-105	
DORIS average	-14			
Average for all	-14			

assumes COM of 942, 0, 0 mm
942 is based on 8 kg hydrazine usage
best estimate indicates only 1.7 kg used, which implies a COM of 937, 0, 0
using 937 increases disparity in estimate by 5 mm

X varies between -5 and -50 mm during sinusoidal yaw
the Z offset increases by 15-20 mm during fixed yaw

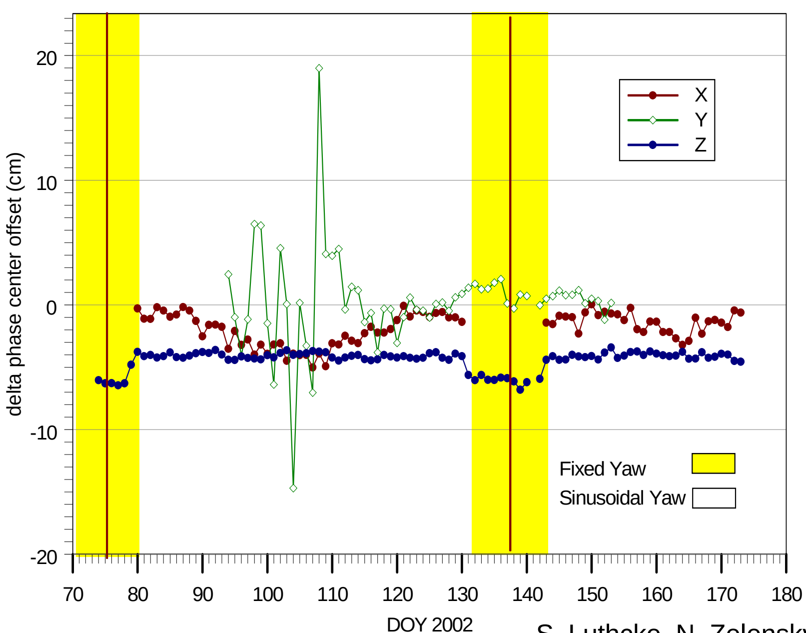
Antenna Phase Center Modeling Issue Identified

Since ~4 cm offset seen only in GPS, must be a technique specific effect

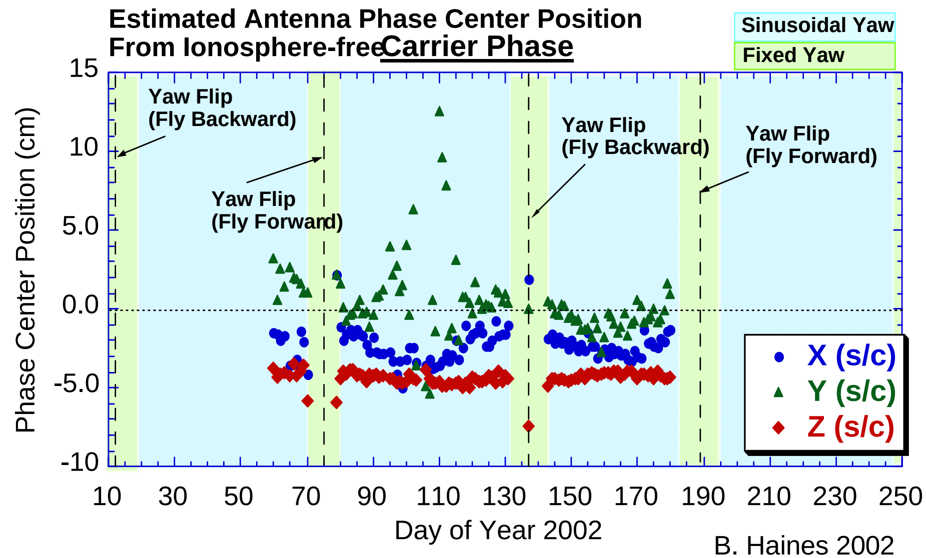
Impact on scale as GPS constellation evolved

Identified as m-level errors in GPS transmitter phase centers

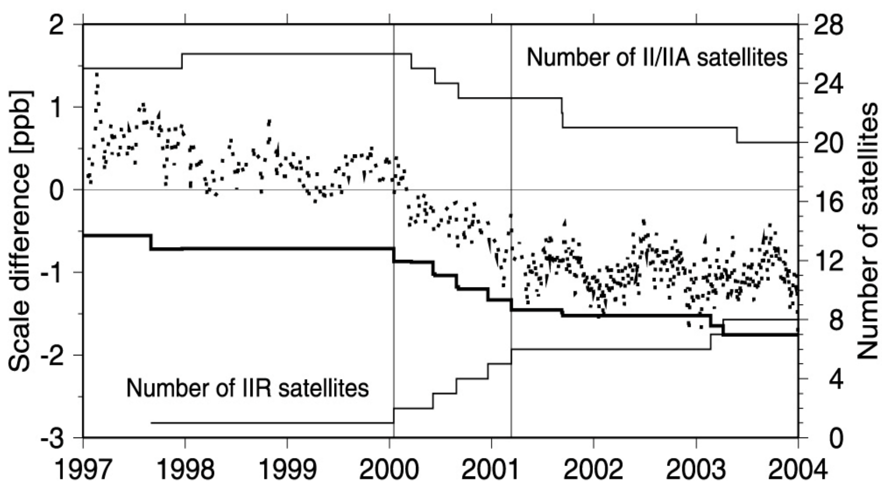
Jason-1 Recovered GPS LC Phase Center Offset Adjustment



S. Luthcke, N. Zelensky 2002

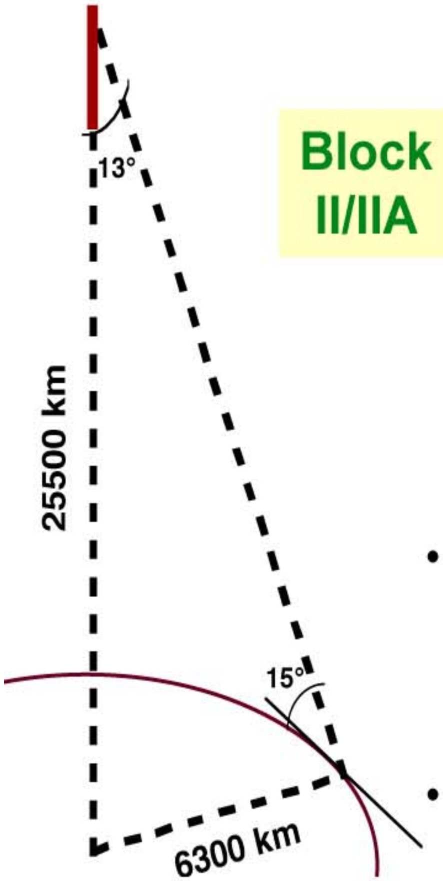


B. Haines 2002



Ge et al., 2005

In-orbit Antenna Phase Center Offset Estimation Campaign



	GPS	GFZ	JPL	CODE	G-J	C-J	G-C
Block II/IIA	Mean	1.01	0.82	0.79	0.19	-0.03	0.21
	Sigma	0.17	0.17	0.16	0.06	0.11	0.13
	GPS43	-0.34	-0.58	-0.21	0.24	0.37	-0.13

The estimated values of SVN43 Z offset are nearly 2 m different than the 'official' value

- Following the campaign the IGS adopted a convention referring the clock solution of Block IIR Z offset to the Center of Mass (CM). Most Analysis Centers implemented Z offset = 0 in their orbit determination software.
- JPL implemented a Z offset of **-0.63** m

Bar Sever, 2005

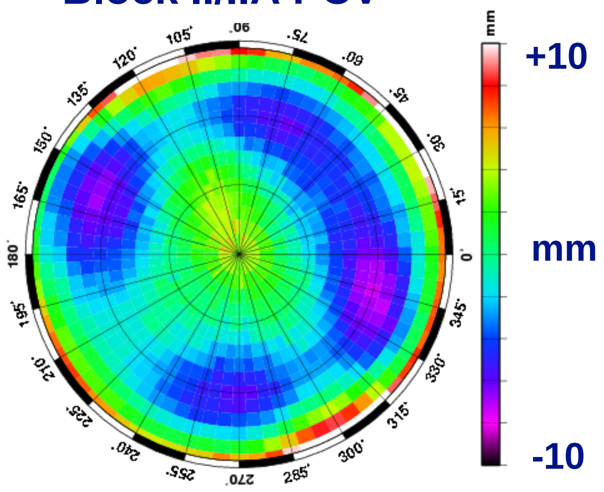
Using GRACE, GPS Phase Center Variations Revealed

Block IIA Antenna
(Mader and Czopek, 2002)

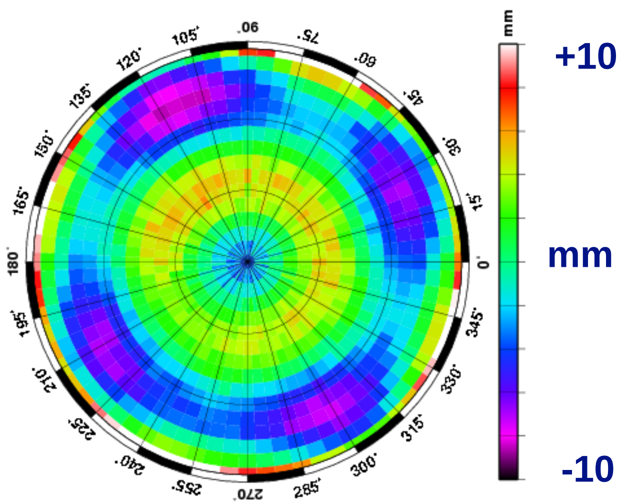
PCV for Ionosphere-free Carrier (LC) with Mean Offset Removed

(Bertiger et al., 2007)

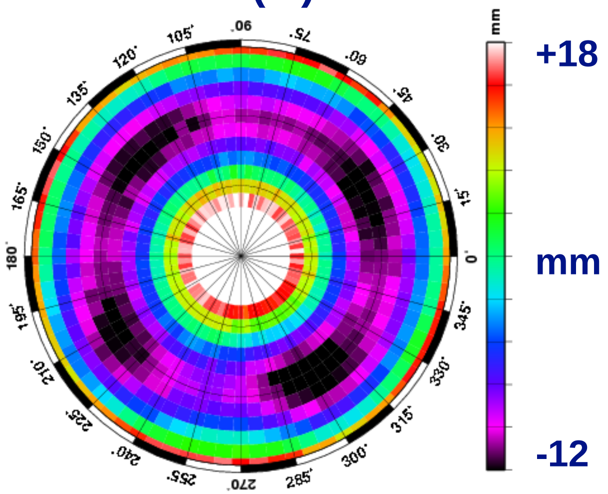
Block II/IIA PCV



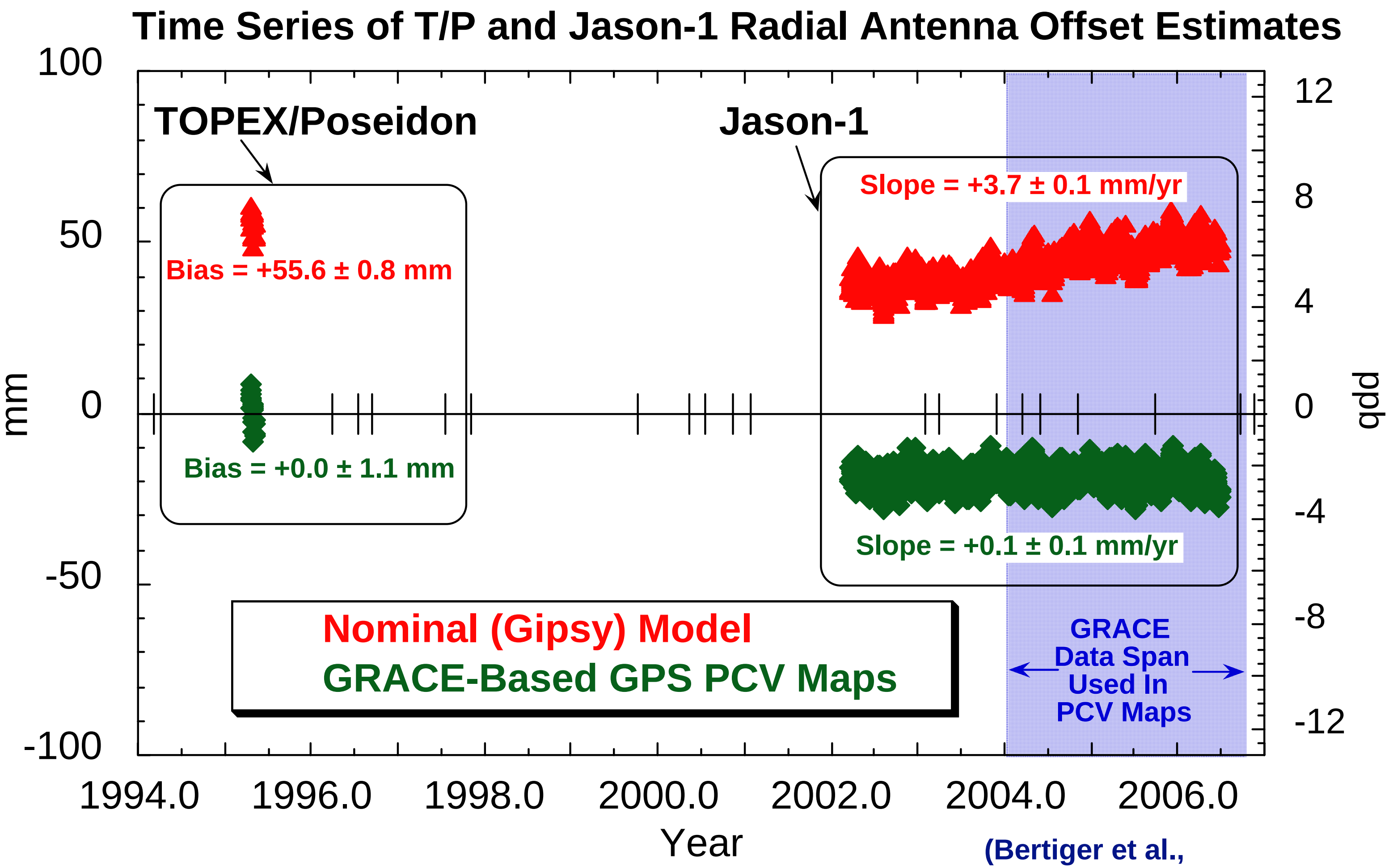
Block IIR-A PCV



Block IIR-B(M) PCV



Apparent Radial Antenna Offsets Explained



(Bertiger et al., 2007)

Challenge: Co-location of SLR on GNSS

SLR phase center on GPS satellites may be in error at the 3-4 cm level

Bias smaller for GLONASS satellites, although orbit accuracy reduced due to smaller observing network

Emphasizes need for accurate CoM and LRA phase center knowledge to fully exploit co-location on satellite

SLR on higher satellites (with accurate CoM knowledge) could provide additional constraints on GM and SLR scale

Statistics for the SLR range residuals derived from more than four years of microwave-based GNSS orbits (final orbits of CODE, GFZ, JPL, and combined IGS final orbits): standard deviation, range bias, and approximate number of normal points used (#np)

PRN	Standard deviation (cm)				Range bias (cm)				#np
	CODE	GFZ	JPL	IGS	CODE	GFZ	JPL	IGS	
G05	2.2	2.3	2.2	1.9	−3.5	−3.6	−2.6	−3.1	11400
G06	2.7	2.7	2.5	2.5	−3.8	−3.9	−2.8	−2.8	10900
R03	4.9				−1.0				17600
R22	4.6				−0.4				21000
R24	5.1				−0.3				12600
R07	5.7				0.5				3200

(Urschl et al., 2007)

Summary

- Co-location on satellite has demonstrated:
  - Identification of systematic errors (CoM and antenna phase center, time tag biases)
  - Verification (orbit accuracy)
  - Calibration (altimeter)
- So far, co-location largely limited to altimeter or low-altitude (high-drag, short-pass) satellites (not optimal for geodesy)
- Co-location on GNSS limited by uncertainties in antenna location (phase center, CoM)