DORIS Satellite Macromodel Updates

F.G. Lemoine

IDS Analysis Working Group Meeting

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Objective

• Analyze recovered daily opr accelerations from DORIS satellite processing (1992-2012), using gscwd15 POD results.

• Perform intercomparisons, and attempt as needed to retune macromodels.

<u>Premise:</u> Reducing opr's amplitudes – improves nonconservative force modelling and reduces draconitic signals in recovered geophysical parameters.

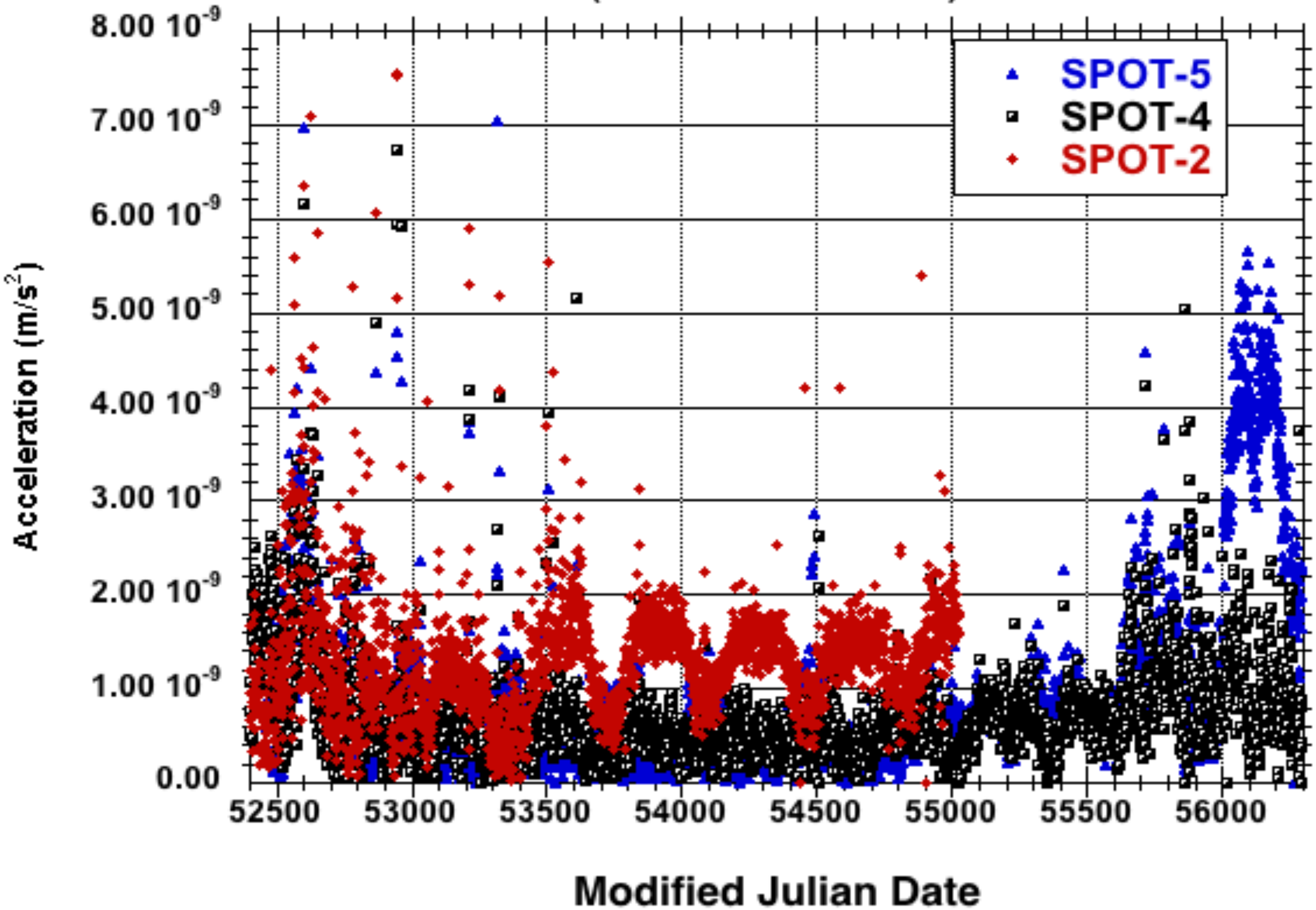
Daily OPR Along-track Acceleration Summary, for gscwd15 series (units of 1.0e-9 m/s²)

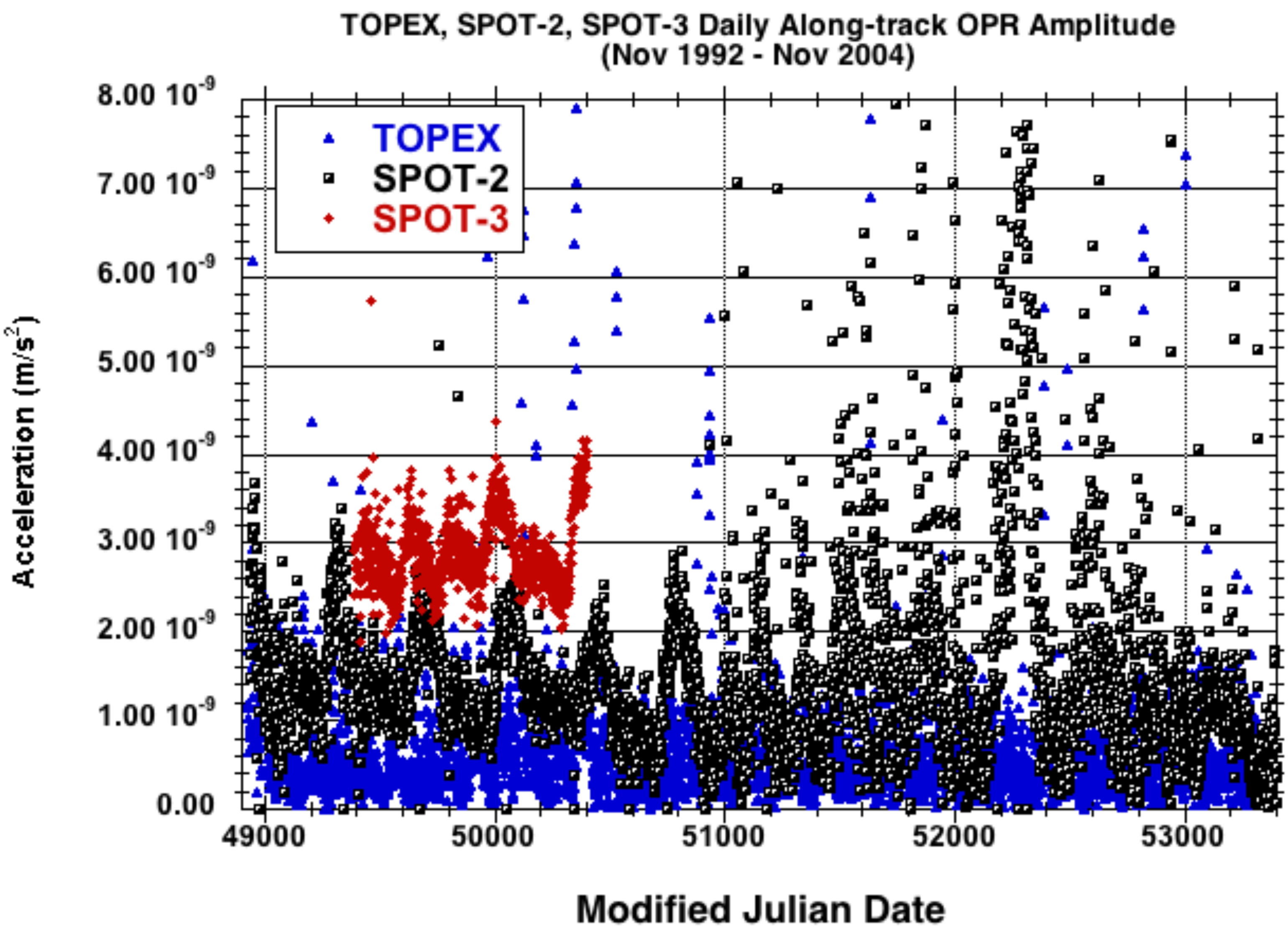
Satellite	Dates	Avg.	Median	Std. Dev
TOPEX	1992-2004	0.88	0.55	2.36
SPOT-2	1992-2009	1.69	1.34	2.55
SPOT-3	1994-1996	3.14	2.82	3.68
SPOT-4	1998-2012	1.15	0.75	1.90
SPOT-5	2002-2012	0.93	0.62	0.98
Envisat	2002-2012	10.5	9.38	3.72
Jason-2	**2008-2012**	**1.31**	**1.04**	**1.09**
Cryosat-2	**2010-2012**	**2.79**	**2.76**	**0.94**
HY-2A	**2011-2012**	**0.91**	**0.64**	**2.07**

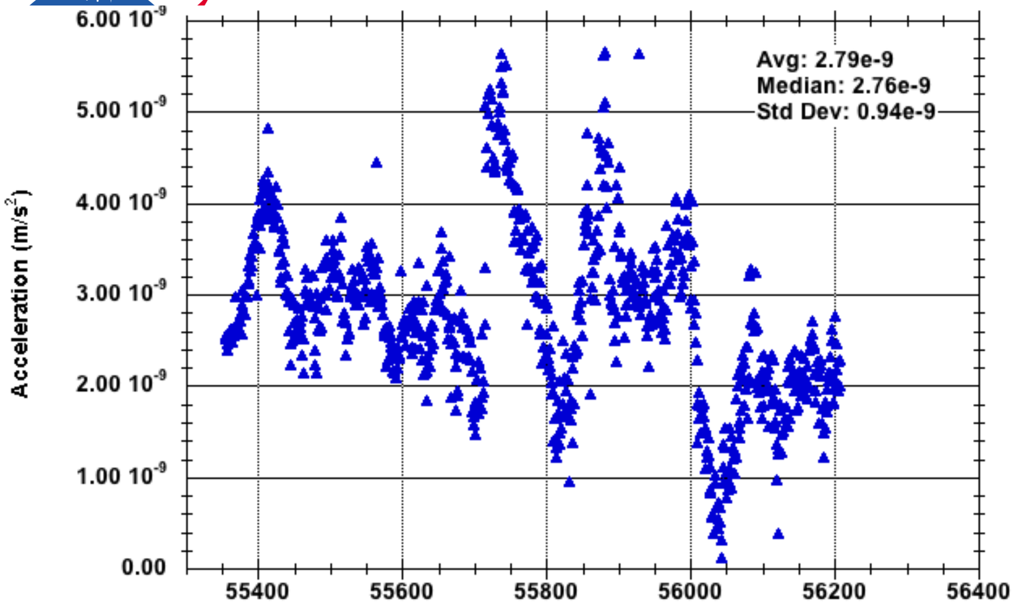
ITRF2008 models

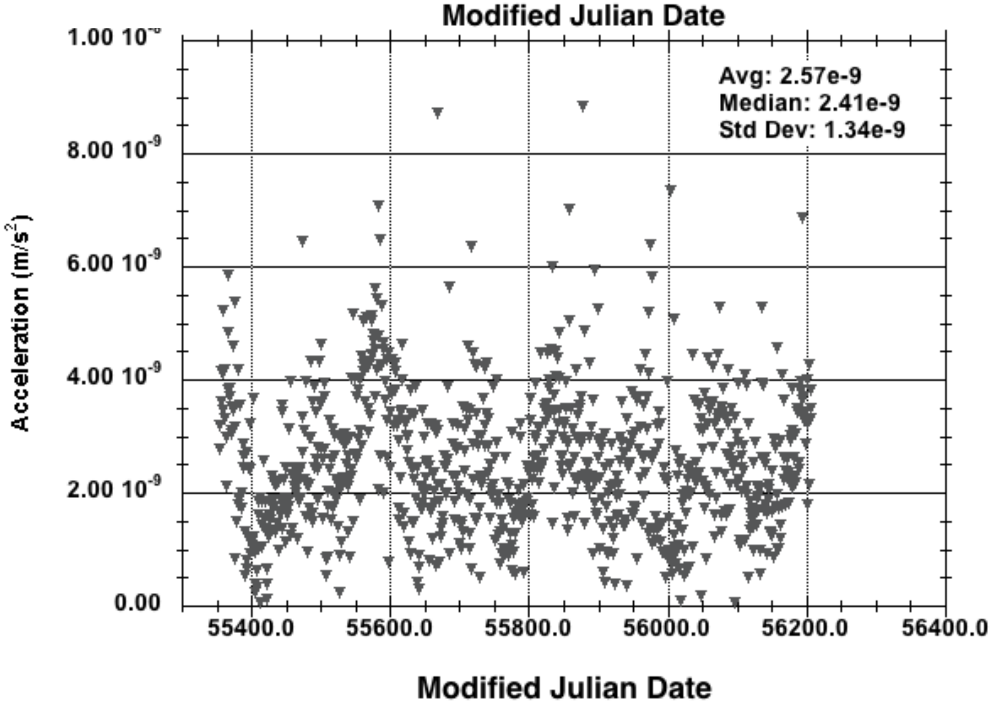
Envisat: UCL model for SRP Drag (*Sibthorpe, 2006*); 10-plate macromodel for P.R.P. & Drag.
SPOT-5: Apply solar array pitch (40°) after January 22, 2008 (No Cr tuning).
Jason-2: Tuned CNES-macromodel, (*Zelensky et al., 2010*)
Cryosat-2: CNES, 7-plate macromodel.
HY-2A: Tuned macromodel (*see GSC HY2A presentation for details*)

SPOT-2, SPOT-4 & SPOT-5 Daily Along-track OPR Amplitude (June 2002 - Dec. 2012)




TOPEX, SPOT-2, SPOT-3 Daily Along-track OPR Amplitude
(Nov 1992 - Nov 2004)
TOPEX
SPOT-2
SPOT-3
Acceleration (m/s^2)
8.00 10^-9
7.00 10^-9
6.00 10^-9
5.00 10^-9
4.00 10^-9
3.00 10^-9
2.00 10^-9
1.00 10^-9
0.00
49000
50000
51000
52000
53000
Modified Julian Date





Cryosat-2 Daily OPR's June 2010-Dec 2012

Along-track (top)

Cross-track (bottom)

Initial attempts at tuning were, unsuccessful. Does effect of AMD-induced jet firings affect macromodel parameter estimation?

NASA GSFC SPOT-2 (a priori) Macromodel

Panel	Unit Vector (X, Y, Z)	Area (m^2)	Specular Reflectivity	Diffuse Reflectivity
+X	(1, 0,0)	4.24680	0.553	0.078
-X	(-1,0,0)	4.24680	0.480	0.058
+Y	(0,1,0)	7.2473	0.632	0.064
-Y	(0,-1,0)	7.2473	0.579	0.090
+Z	(0,0,1)	6.87398	0.592	0.091
-Z	(0,0,-1)	6.87398	0.522	0.028
Solar Array+ (SA+, toward Sun)	(0.3338068, -0.942664149 , 0.0)	19.2255	0.223	0.120
Solar Array- (SA-, antiSun)	(-0.33380686, +0.94264140 , 0.0)	19.2255	0.319	0.183

The solar arrays are moveable panels and track the Sun. The unit vectors for the solar array account for the 19.5° offset of the panels in the GEODYN software.

The NASA GSFC macromodel for SPOT-2 was derived in the early 1990’s (Gitton & Kneib, 1990).

For ITRF2008, we solved for two separate Cr values with respect to this macromodel for SPOT-2 (Cr=1.0386, 1993-2002; Cr=1.0716, 2003-2008) See Figure 1 in Le Bail et al. (2010),

For GSCWD15, we applied Cr = 1.0386 for SPOT-2.

References:

(1) Gitton, P., Kneib, J., Influence of the surface forces on the orbit of the SPOT satellite. Internal Report. Colorado Center for Astrodynamics Research, University of Colorado, Boulder, July 1990.

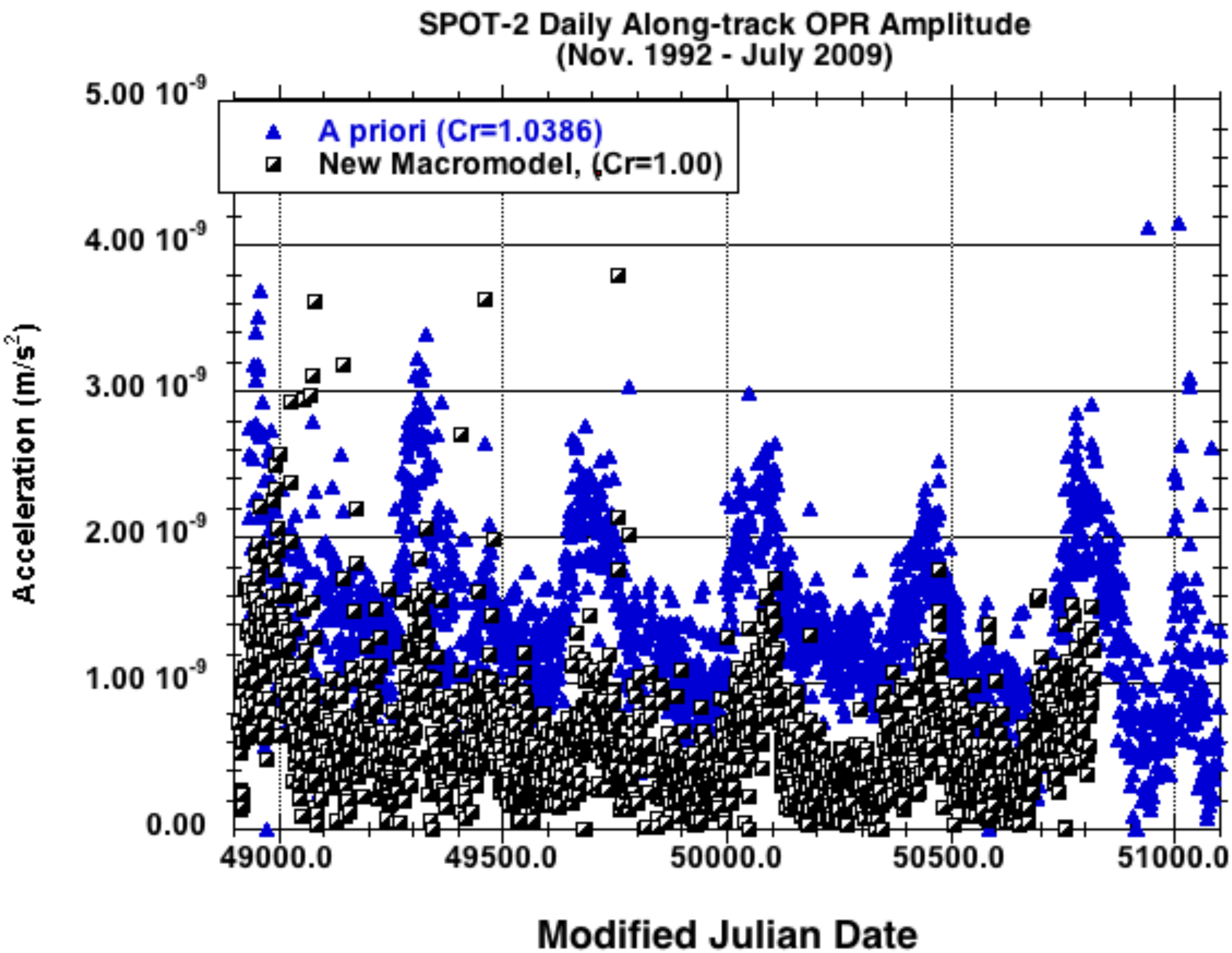
(2) Le Bail, K., F.G. Lemoine, D.S. Chinn (2010), GSFC DORIS Contribution to ITRF2008, Adv. Space Research, 45, 1481-1499, doi: 10.1016/j.asr.2010.01.030

NASA GSFC SPOT-2 (2013-retuned) Macromodel

Panel	Unit Vector (X, Y, Z)	Area (m^2)	Specular Reflectivity	Diffuse Reflectivity
+X	(1, 0,0)	4.24680	0.553	0.078
-X	(-1,0,0)	4.24680	0.480	0.058
+Y	(0,1,0)	7.2473	0.632	0.064
-Y	(0,-1,0)	7.2473	**0.6789**	0.090
+Z	(0,0,1)	6.87398	0.592	0.091
-Z	(0,0,-1)	6.87398	0.522	0.028
Solar Array+ (SA+, toward Sun)	(0.3338068, -0.942664149 , 0.0)	19.2255	**0.3102**	0.120
Solar Array- (SA-, antiSun)	(-0.33380686, +0.94264140 , 0.0)	19.2255	0.319	0.183

SPOT-2 Macromodel Tests (1993 – 1997)

Test	Along-track (units, 1.0e-9 m/s^2)		Cross-track (units, 1.0e-9 m/s^2)		
	Median	Mean	Median	Mean	
Nominal	1.379	1.552	2.511	3.011	Cr=1.0386
Ptest3	0.548	0.739	2.701	3.024	Cr=1.00



SPOT-2 Daily Along-track OPR Amplitude
(Nov. 1992 - July 2009)
A priori (Cr=1.0386)
New Macromodel, (Cr=1.00)
Acceleration (m/s^2)
5.00 10^-9
4.00 10^-9
3.00 10^-9
2.00 10^-9
1.00 10^-9
0.00
49000.0
49500.0
50000.0
50500.0
51000.0
Modified Julian Date

NASA GSFC SPOT-3 a priori Macromodel

(Le Bail et al., 2010)

Panel	Unit Vector (X, Y, Z)	Area (m^2)	Specular Reflectivity	Diffuse Reflectivity
+X	(1, 0,0)	6.69	0.540	0.07
-X	(-1,0,0)	6.69	0.540	0.07
+Y	(0,1,0)	6.51	0.54	0.064
-Y	(0,-1,0)	6.51	0.767	0.090
+Z	(0,0,1)	3.515	0.592	0.091
-Z	(0,0,-1)	3.515	0.522	0.028
Solar Array+ (SA+, toward Sun)	(0.3338068, -0.942664149 , 0.0)	19.5	0.273	0.120
Solar Array- (SA-, antiSun)	(-0.33380686, +0.94264140 , 0.0)	19.5	0.319	0.183

The solar arrays are moveable panels and track the Sun. The unit vectors for the solar array account for the 19.5° offset of the panels in the GEODYN POD software.

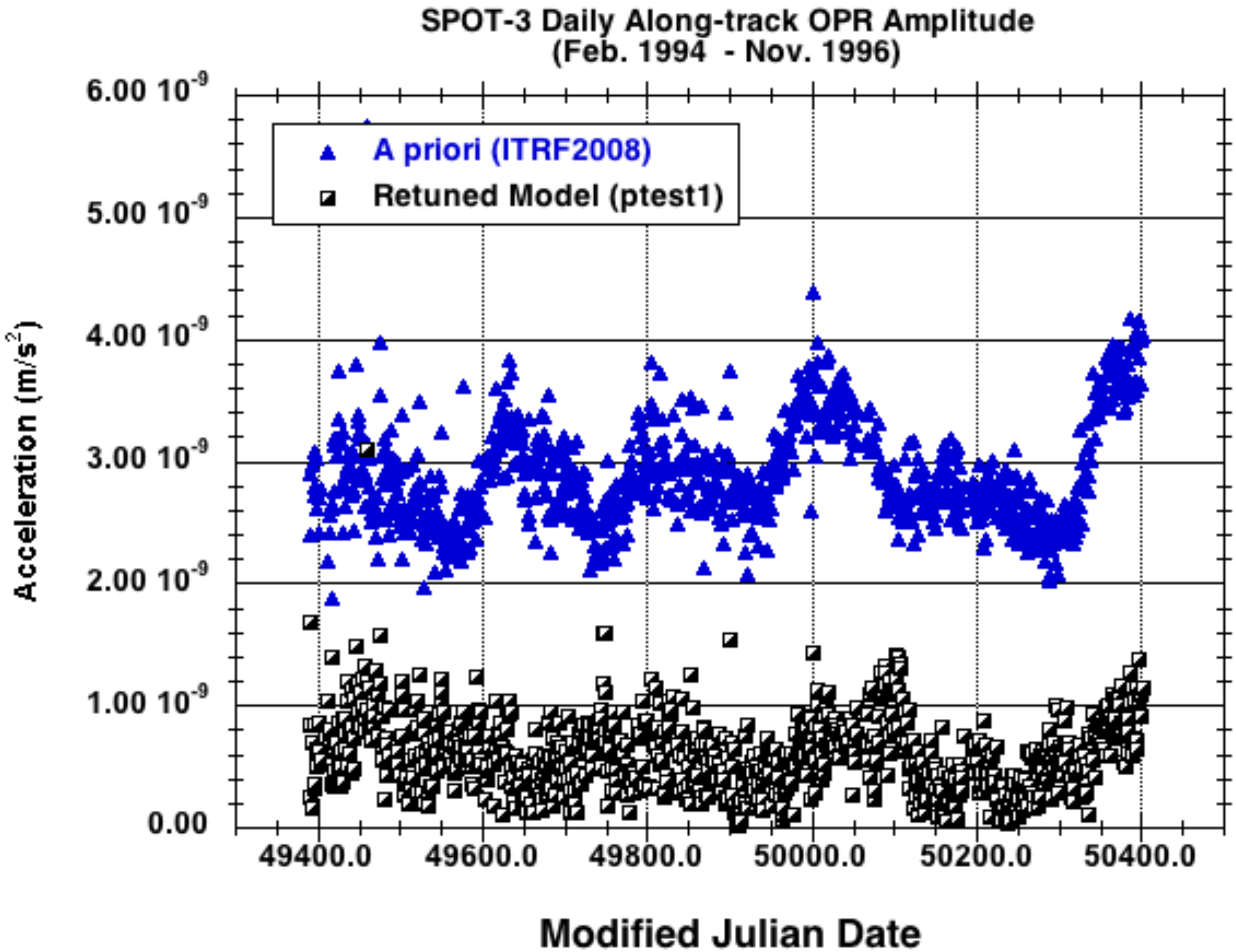
NASA GSFC SPOT-3 Retuned Macromodel
(February 2013)

Panel	Unit Vector (X, Y, Z)	Area (m^2)	Specular Reflectivity	Diffuse Reflectivity
+X	(1, 0,0)	6.69	0.540	0.07
-X	(-1,0,0)	6.69	0.540	0.07
+Y	(0,1,0)	6.51	0.54	0.064
-Y	(0,-1,0)	6.51	0.767	0.090
+Z	(0,0,1)	3.515	0.592	0.091
-Z	(0,0,-1)	3.515	0.522	0.028
Solar Array+ (SA+, toward Sun)	(0.3338068, -0.942664149 , 0.0)	19.5	**0.3359**	0.120
Solar Array- (SA-, antiSun)	(-0.33380686, +0.94264140 , 0.0)	19.5	0.319	0.183

After various tests, we find that it is only worthwhile to tune the specular reflectivity of the solar array

SPOT-3 Macromodel Tests (1994 – 1996)

Test	Along-track (units, 1.0e-9 m/s^2)		Cross-track (units, 1.0e-9 m/s^2)		
	Median	Mean	Median	Mean	
Nominal	3.13	3.20	2.20	2.47	Cr=1.00
Ptest1	0.586	0.601	2.151	2.401	Cr=1.00


SPOT-3 Daily Along-track OPR Amplitude
(Feb. 1994 - Nov. 1996)
A priori (ITRF2008)
Retuned Model (ptest1)
Acceleration (m/s²)
6.00 10⁻⁹
5.00 10⁻⁹
4.00 10⁻⁹
3.00 10⁻⁹
2.00 10⁻⁹
1.00 10⁻⁹
0.00
49400.0
49600.0
49800.0
50000.0
50200.0
50400.0
Modified Julian Date

SPOT-4 & SPOT-5:

- **Based on opr's, Retuning of macromodel does not seem to be necessary;**

NASA GSFC SPOT-4 8-plate Macromodel

(Le Bail et al., 2010)

Panel	Unit Vector (X, Y, Z)	Area (m^2)	Specular Reflectivity	Diffuse Reflectivity
+X	(1, 0,0)	3.5	0.54	0.07
-X	(-1,0,0)	3.5	0.63	0.81
+Y	(0,1,0)	7.7	0.213	0.500
-Y	(0,-1,0)	7.7	0.560	0.380
+Z	(0,0,1)	9.0	0.47	0.11
-Z	(0,0,-1)	9.0	0.47	0.25
Solar Array+ (SA+, towards Sun)	(0.08715507, -0.99619500)	24.8	0.342	0.150
Solar Array- (SA-, away from Sun)	(-0.08715507, +0.99619500)	24.8	0.240	0.240

NASA GSFC SPOT-5 8-plate Macromodel

(Le Bail et al., 2010**)**

Panel	Unit Vector (X, Y, Z)	Area (m^2)	Specular Reflectivity	Diffuse Reflectivity
+X	(1, 0,0)	7.21	0.5255	0.261
-X	(-1,0,0)	7.21	0.161	0.051
+Y	(0,1,0)	10.79	0.475	0.368
-Y	(0,-1,0)	10.79	0.6731	0.366
+Z	(0,0,1)	11.79	0.370	0.201
-Z	(0,0,-1)	11.79	0.393	0.262
Solar Array+ (SA+, towards Sun)	(0.08715570, -0.99619500)	24.795	0.1676	0.150
Solar Array- (SA-, away from Sun)	(-0.08715570, +0.99619500)	24.795	0.240	0.240

ENVISAT Daily OPR Along-track Acc. Summary

(units of 1.0e-9 m/s^2, Jan 2004 to October 2005)

Test	Nplates	UCL model applied	Along-track OPR Ampl (1 x 10^{-9} m/s^2)		Cross-track OPR Amplitude (1 x 10^{-9} m/s^2)		Cr
Satellite			Avg.	Median	Avg	Median	
A priori	10	Y	10.29	9.98	2.573	2.204	1.00
mod	10	Y	1.517	1.418	1.980	1.661	1.00
mod_noucl	10	N	0.897	0.847	2.160	1.859	1.00
Ucltst1*	10	Y	1.096	1.032	1.946	1.629	1.00
Ucltst1_cr*	10	Y	1.076	1.007	1.945	1.622	1.00417
cnesmod	8	Y	1.571	1.475	1.958	1.633	1.00
cnesmod_noucl	8	N	1.337	1.265	2.119	1.796	1.00

Conclusions: (1) 10 –plate macromodel (includes SAR-array) slightly lower opr 'residuals' than 8-plate (CNES) model; (2) UCL-model improves after application of correction in surface area for thermal re-radiation of solar array.

Envisat 10-plate Macromodel
(IDS website … Heritage = ?)

Panel	Unit Vector (X, Y, Z)	Area (m^2)	Specular Reflectivity	Diffuse Reflectivity
+X	(1, 0,0)	9.73	0.1800	0.767
-X	(-1,0,0)	9.73	0.110	0.591
+Y	(0,1,0)	22.92	0.187	0.320
-Y	(0,-1,0)	22.92	0.187	0.303
+Z	(0,0,1)	26.24	0.208	0.420
-Z	(0,0,-1)	26.24	0.189	0.362
SAR+	(-0.439, 0 -0.898)	13.40	0.018	0.053
SAR-	(0.439, 0, 0.898)	13.40	0.027	0.029
Solar Array+ (SA+, towards Sun)	(0.374606593, -0.92718385, 0)	71.119	0.208	0.052
Solar Array- (SA-, away from Sun)	(-0.374606593, 0.92718385,0)	71.119	0.112	0.448

Solar array unit vectors represent 22° pitch offset

Envisat 8-plate Macromodel

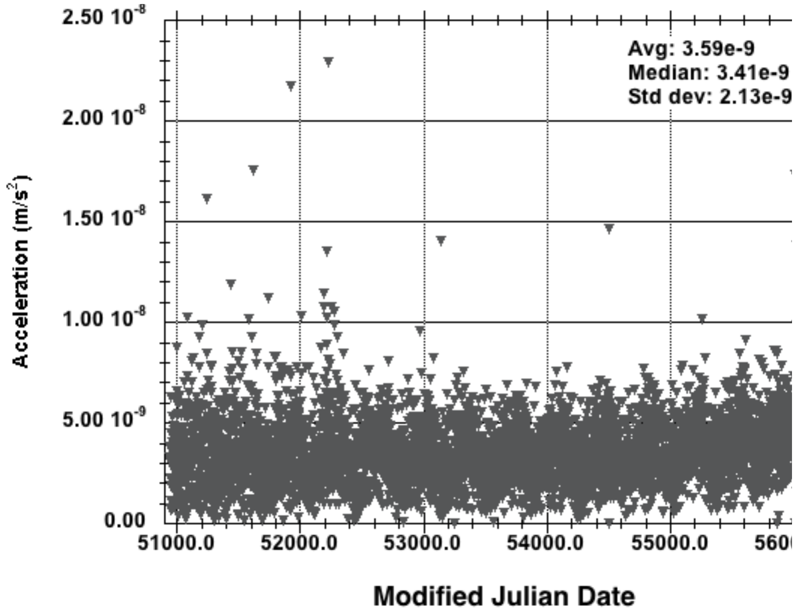
(CNES Document; Cerri & Ferrage, April 2011**)**

Panel	Unit Vector (X, Y, Z)	Area (m^2)	Specular Reflectivity	Diffuse Reflectivity
+X	(1, 0,0)	15.64	0.177	0.451
-X	(-1,0,0)	15.64	0.098	0.434
+Y	(0,1,0)	22.92	0.146	0.459
-Y	(0,-1,0)	22.92	0.146	0.442
+Z	(0,0,1)	38.26	0.184	0.264
-Z	(0,0,-1)	38.26	0.163	0.274
Solar Array+ (SA+, towards Sun)	(0.374606593, -0.92718385, 0)	71.119	0.208	0.052
Solar Array- (SA-, away from Sun)	(-0.374606593, 0.92718385,0)	71.119	0.112	0.448

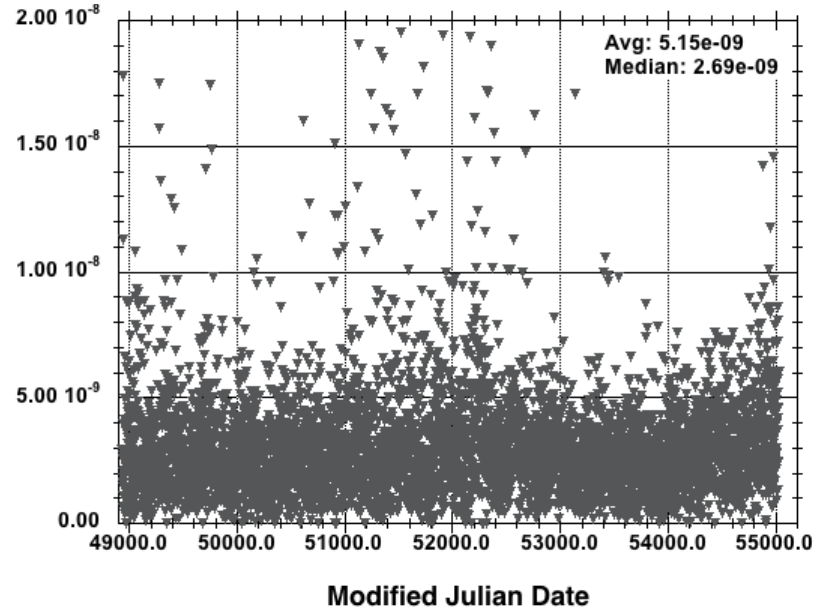
Solar array unit vectors represent 22° pitch offset

Cross-track accelerations (examples)

SPOT-4 Daily Cross-track OPR Amplitude (May 1998 – Dec. 2012)



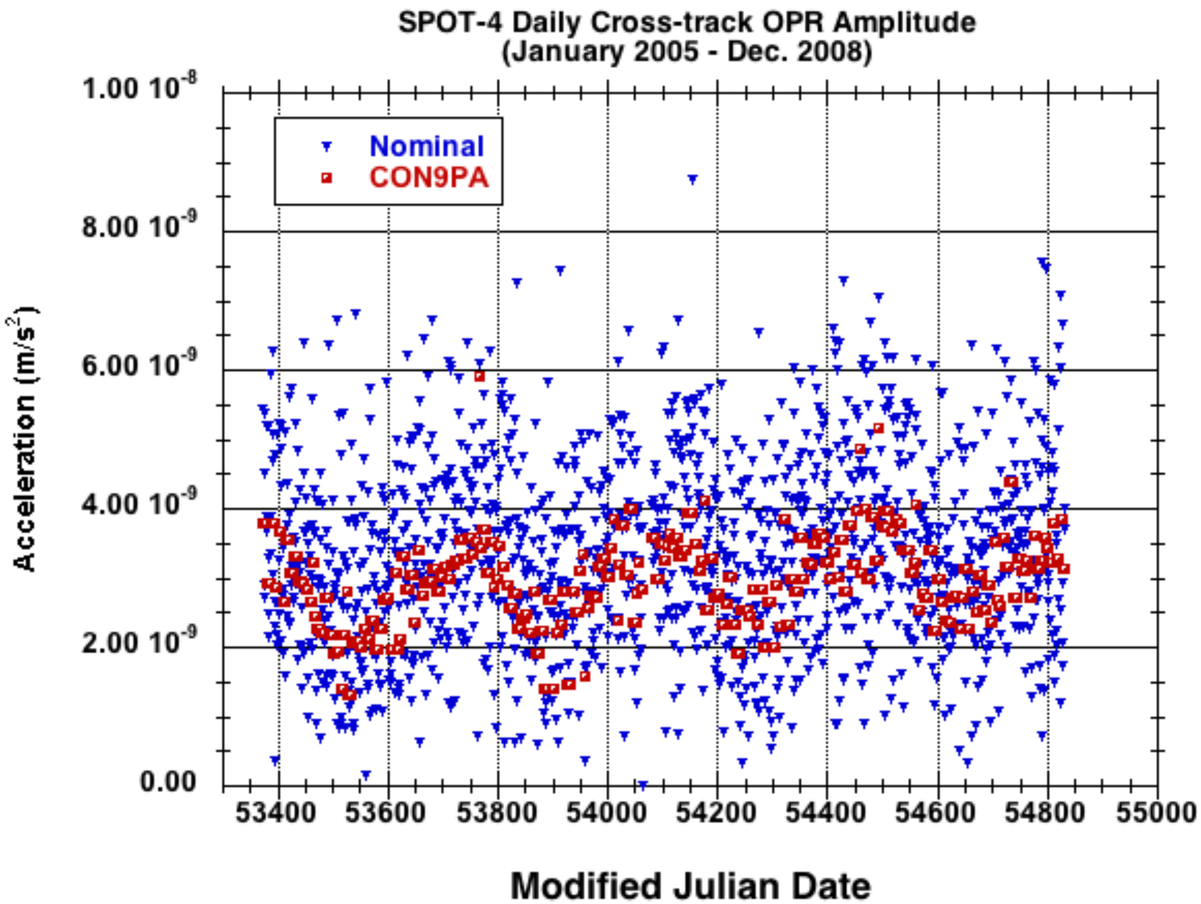
SPOT-5 Daily Cross-track OPR Amplitude (June 2002 – Dec. 2012)



1. Macromodel tuning generally does not seem to diminish the residual cross-track accelerations.
2. The cross-track acceleration for the most part appears more stochastic.
3. Do the data allow the cross-track OPR/day necessarily to be resolved?

Cross-track accelerations
(Unmodelled signal?)

1. Adjust cross-track opr/arc – instead of opr/day (SPOT-4)
2. No change to along-track opr/day, parameterization



Summary

1. At GSFC we have retuned the macromodels for SPOT-2, SPOT-3; These seem to reduce amplitude of along-track accelerations (Reduce nonconservative force mismodelling).

2. For Envisat: Either 8-plate, 10-plate macromodel, or UCL model give very similar performances for nonconservative force modelling; If using the UCL (Envisat) model, -> A macromodel must still be used to model atmospheric drag and planetary radiation pressure.

3. Cryosat-2: No success retuning model parameters. (AMD effects?)
4. Jason-2: Beta prime signal remains in OPR, and in dynamic orbits (Zelensky et al., 2010; Cerri et al., 2010)

5. Cross-track accelerations: for more sparsely tracked SPOT satellites – is a cross-track opr/day necessarily resolvable? What is the nature of annual signal in the cross-track?

6. Test new UCL models for DORIS satellites – when they become available.