

TASK 12: BIOFIDELITY EVALUATION OF ROLLOVER CRASH ATD

Rollover Buck Kinematic Test without Roof

Polar II, WorldSID

Tests

UVAV1968-2030

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A Report Prepared for NHTSA

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by the

Center for Applied Biomechanics
Automobile Safety Laboratory
University of Virginia

Principal Investigator
Jeff Crandall



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INTRODUCTION

Though rollover occurs in only 2.2% of all motor vehicle crashes, these crashes are responsible for over one third of all motor vehicle crash fatalities (NHTSA 2010). Numerous previous research studies have utilized anthropometric test devices (ATD) to study occupant dynamics and injury risk in rollover crashes. While the 50th percentile male Hybrid III ATD was designed to predict occupant kinematics/kinetics and injury risk in frontal crashes, it has been frequently used for rollover crash research. Moffatt et al. (1997, 2003) conducted tests with the Hybrid III ATD, the Hybrid III ATD with a pedestrian pelvis, human volunteers and a cadaver to measure and compare head excursions between the subjects in pure rotation tests. The authors compared vertical head excursions between the subjects as a means of evaluating ATD biofidelity and restraint system characteristics. While the magnitude of head vertical excursion can influence injury risk, a biofidelity analysis that examines whole-body three-dimensional motion provides for a more complete basis on which to evaluate subject variations. Consideration of multiple body segment kinematics ensures that intersegment stiffness is assessed, and three-dimensional analysis permits examination of not only vertical but lateral and out-of-plane motion, which can affect occupant position and orientation at impact, and thus injury risk. In addition, the kinetic response of the ATDs (boundary conditions), which determine the interaction of occupant with the environment (seat, belts et al), should also be considered in the ATD biofidelity evaluation.

The current study is the first part of a multi-step research effort aimed at ultimately developing an ATD for rollover crash study. Tests were conducted using a vehicle test buck developed to mimic the inertial, geometric, and strength properties of a full-size crossover developed for the US market. The buck kinematics simulated the occupant loading modes in rollover crashes, which include centrifugal acceleration resulted from the vehicle rotational motion and linear vertical deceleration resulted from the roof-to-ground interaction. The buck kinematics was achieved by rotating the buck using the Dynamic Rollover Test System (DRoTS) to simulate the centrifugal acceleration, and releasing the buck and caught by square tubing decelerator to simulate the linear vertical acceleration.

The primary goal of this study was to characterize and assess the kinematic response biofidelity of six existing ATDs (Hybrid III (H3), Hybrid III Pedestrian (H3P), Polar II, WorldSID, Hybrid III with Pedestrian Pelvis (H3PP) and THOR) by comparing with PMHS kinematics response targets published by Lessley et al. (2014), and the secondary goal was to evaluate and compare the kinematic response differences among these ATDs. This report describes briefly the test methodology, the test fixture, and results of the study. More complete information and in depth analysis are available in the paper to be published in the STAPP 2014 conference titled “Occupant Kinematics in Laboratory Rollover Tests: ATD Response and Biofidelity”.

Test Setup and Coordinate Systems

Two coordinate systems are used to present data from the tests. The buck or local coordinate system, which remained fixed to the vehicle, was defined using standardized conventions (SAE J211, 1995) (Figure 1). The positive X axis pointed from the rear to the front of the vehicle. The positive Y axis pointed from the vehicle left hand side (driver's side) to the vehicle right hand side (passenger side). The positive Z axis pointed from the top to the bottom of the vehicle. The global or inertial reference frame, was defined by the direction of the road bed travel (Figure 29). The roadbed traveled in the positive X direction. The Z axis was oriented normal to the test facility floor, with positive pointing downward. The positive Y-axis was mutually perpendicular to the X and Z axes, with positive pointing from control arm 1 to control arm 2 (vehicle front to rear) (Figure 1).

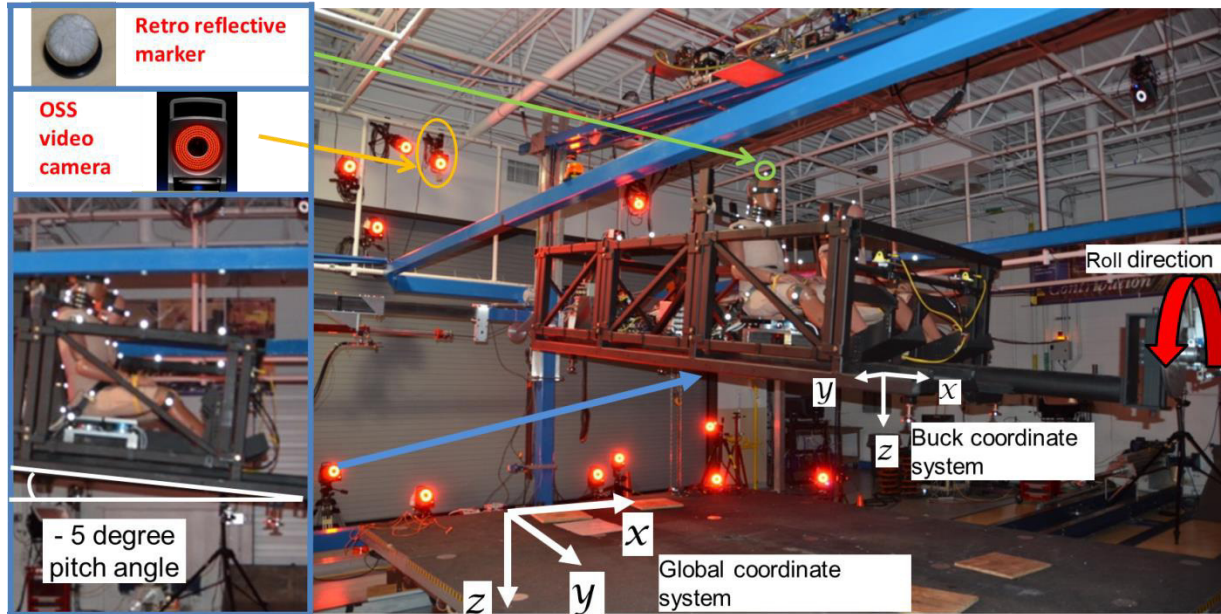


Figure 1. DROTTS rollover buck testing system overview

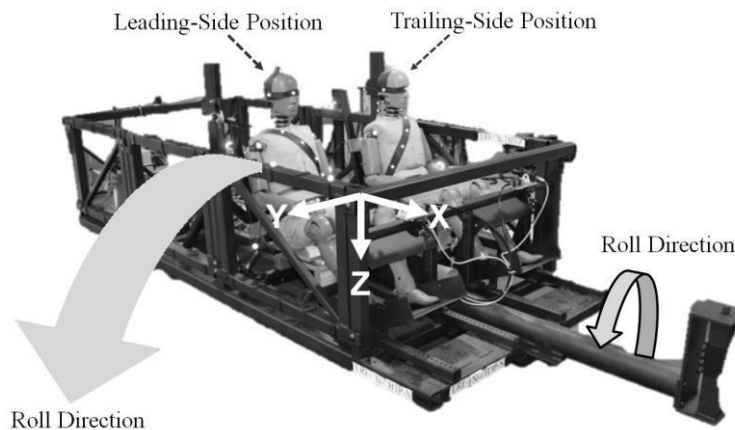


Figure 2. Parametric vehicle buck, seating positions, roll direction, and SAE vehicle coordinate system. Illustrated with 50th percentile Hybrid III ATDs occupying both seats.

ATD Instrumentation

Each of the ATDs was instrumented at least with 6-DOF head cube sensors (3-axis acceleration and 3-axis angular rate sensors), a 3-axis chest CG accelerometer cube and a 3-axis pelvis accelerometer cube, to measure the surrogates kinematics response in the tests. For the ATDs, additional instrumentations were available depending on the specific ATD instrumentation when received for testing.

High Speed Video

Three off-board high speed digital imagers (GX-1, NAC Image Technology, Simi Valley, CA) were used to capture video of each test (Figure 3). Additionally, two high speed digital cameras were installed in front of the buck to provide the buck onboard front view of occupant kinematics and one high speed digital cameras (HR-CAM,GX-5, NAC Image Technology, Simi Valley, CA) were installed in the back of the buck to provide a buck onboard rearview of the occupant motion (Figure 4).

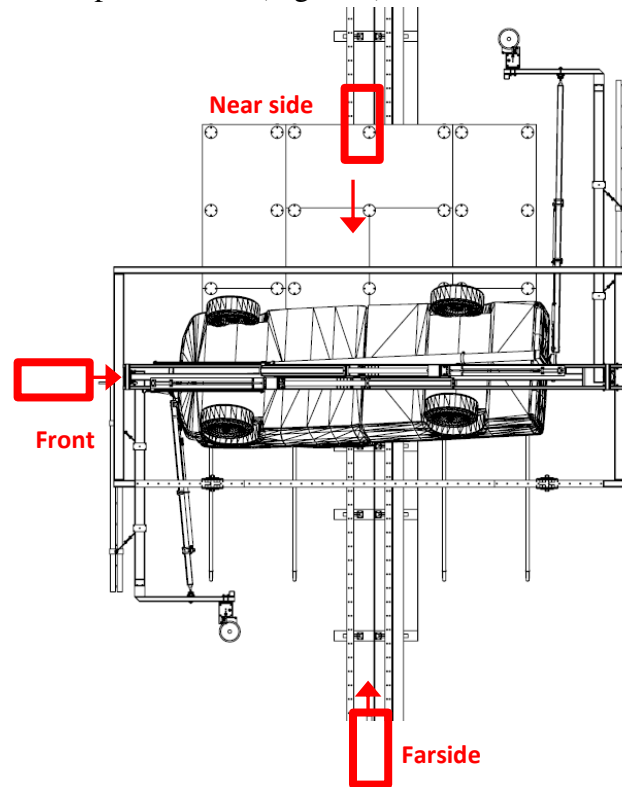


Figure 3. Offboard high-speed imager placement.

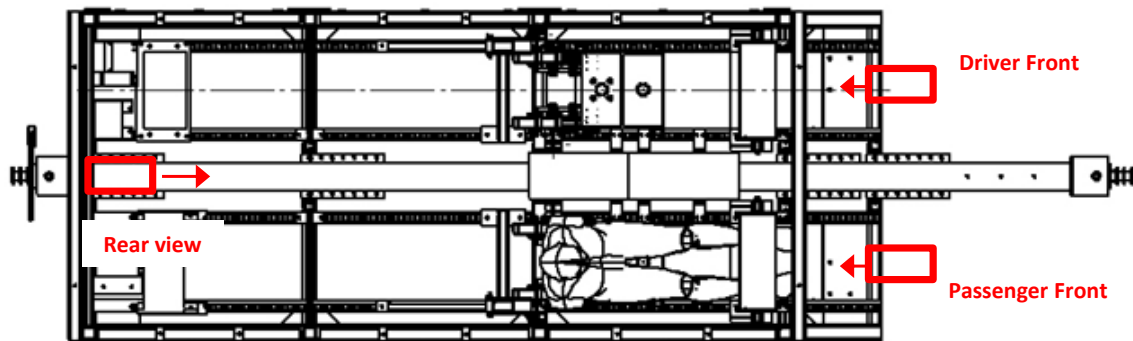


Figure 4. Onboard high-speed imager placement (top view of the buck)

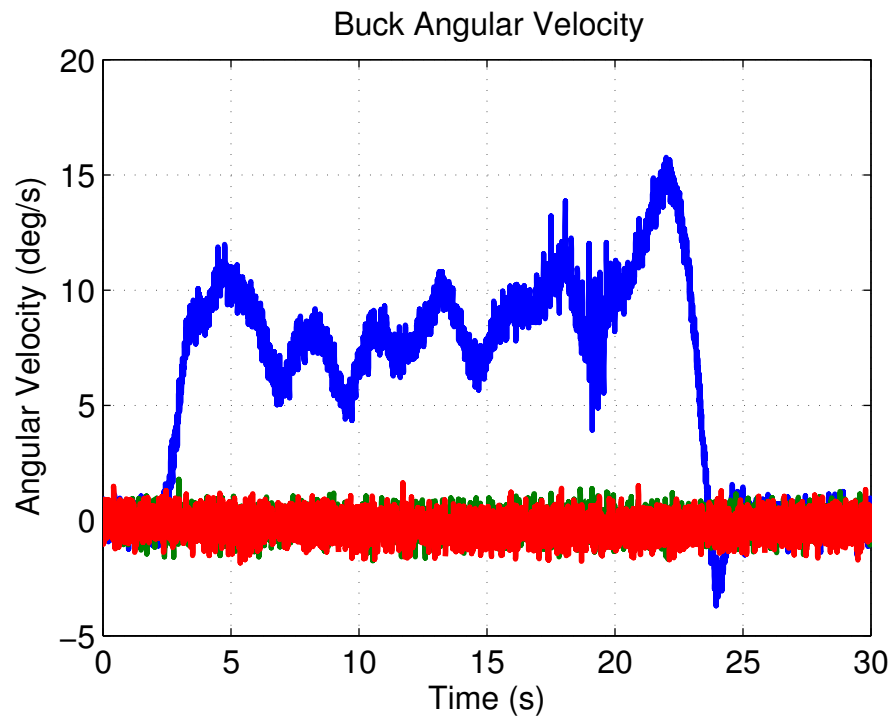
ATD Injury Criteria/Metric Calculation

In the buck kinematic tests without roof, the occupants (PMHS in the current study) were subjected under rollover kinematics without the actual roof-to-road/ground impact, with no injuries expected for any of the occupants. In addition, the acceleration level measured by the accelerometer mounted on the ATD was also too low to be able to indicate any injury. Therefore, none of the injury metric was calculated for the kinematic tests.

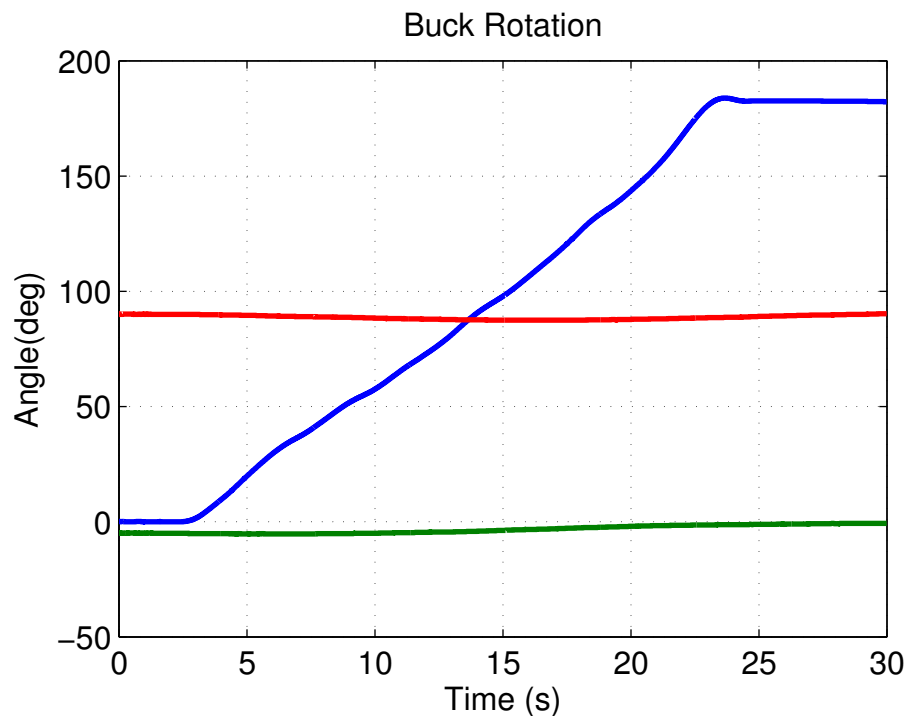
Table 1 ATD Test Matrix

Test_ID	Test_Type	Trailing_Side	Leading_Side	Belt_Condition	Test Comments
1968QR	QR	WorldSID	PolarII	Nominal	Quasistatic Roll, 35 N Belt Tension
1968	D	WorldSID	PolarII	Nominal	Inverted Drop, 35 N Belt Tension
1969	LR	WorldSID	PolarII	Nominal	180 deg/s Roll, 35 N Belt Tension
1970	HR	WorldSID	PolarII	Nominal	360 deg/s roll, 35 N Belt Tension
1971	HRN	WorldSID	PolarII	Nominal	360 deg/s Roll with leading side drop, 35 N Belt Tension
1972	HRF	WorldSID	PolarII	Nominal	360 deg/s Roll with trailing side drop, 35 N Belt Tension
1973	LRN	WorldSID	PolarII	Nominal	180 deg/s Roll with leading side drop, 35 N Belt Tension
1981	LR	WorldSID	PolarII	Pretensioned	180 deg/s Roll, 300 N Belt Tension
1982	HR	WorldSID	PolarII	Pretensioned	360 deg/s roll, 300 N Belt Tension
1983	HRN	WorldSID	PolarII	Pretensioned	360 deg/s Roll with leading side drop, 300 N Belt Tension
1987	HRF	WorldSID	PolarII	Pretensioned	360 deg/s Roll with trailing side drop, 300 N Belt Tension
1994	HRN	WorldSID	PolarII	5_Newtons	360 deg/s Roll with leading side drop, 5 N Belt Tension
1996	LRF	WorldSID	PolarII	Nominal	180 deg/s Roll with trailing side drop, 35 N Belt Tension
1997	LRN	WorldSID	PolarII	Nominal	180 deg/s Roll with leading side drop, 35 N Belt Tension
1998	HR	WorldSID	PolarII	Nominal	360 deg/s roll, 35 N Belt Tension
1999	HR	WorldSID	PolarII	Nominal	360 deg/s roll, 35 N Belt Tension
2000	HRN	WorldSID	PolarII	Nominal	360 deg/s Roll with leading side drop, 35 N Belt Tension
2001	LR	WorldSID	PolarII	5_Newtons	180 deg/s Roll, 5 N Belt Tension
2002	LR	WorldSID	PolarII	5_Newtons	180 deg/s Roll, 5 N Belt Tension
2003	HR	WorldSID	PolarII	Pretensioned	360 deg/s roll, 300 N Belt Tension
2004	LRN	WorldSID	PolarII	Pretensioned	180 deg/s Roll with leading side drop, 300 N Belt Tension
2005QR	QR	WorldSID	PolarII	Pretensioned	Quasistatic Roll, 300 N Belt Tension
2005	D	WorldSID	PolarII	Pretensioned	Inverted Drop, 300 N Belt Tension
2006QR	QR	WorldSID	PolarII	5_Newtons	Quasistatic Roll, 5 N Belt Tension
2006	D	WorldSID	PolarII	5_Newtons	Inverted Drop, 5 N Belt Tension
2007QR	QR	PolarII	WorldSID	Nominal	Quasistatic Roll, 35 N Belt Tension
2007	D	PolarII	WorldSID	Nominal	Inverted Drop, 35 N Belt Tension
2008QR	QR	PolarII	WorldSID	Nominal	Quasistatic Roll, 35 N Belt Tension
2008	D	PolarII	WorldSID	5_Newtons	Inverted Drop, 5 N Belt Tension
2009	LR	PolarII	WorldSID	5_Newtons	180 deg/s Roll, 5 N Belt Tension
2010	LR	PolarII	WorldSID	5_Newtons	180 deg/s Roll, 5 N Belt Tension
2011	HRN	PolarII	WorldSID	5_Newtons	360 deg/s Roll with leading side drop, 5 N Belt Tension

2012	LR	PolarII	WorldSID	Nominal	180 deg/s Roll, 35 N Belt Tension
2013	HR	PolarII	WorldSID	Nominal	360 deg/s roll, 35 N Belt Tension
2014	HR	PolarII	WorldSID	Nominal	360 deg/s roll, 35 N Belt Tension
2015	HRN	PolarII	WorldSID	Nominal	360 deg/s Roll with leading side drop, 35 N Belt Tension
2018	HRF	PolarII	WorldSID	Nominal	360 deg/s Roll with trailing side drop, 35 N Belt Tension
2021	LRN	PolarII	WorldSID	Nominal	180 deg/s Roll with leading side drop, 35 N Belt Tension
2022	LRN	PolarII	WorldSID	Nominal	180 deg/s Roll with leading side drop, 35 N Belt Tension
2023	LRN	PolarII	WorldSID	Pretensioned	180 deg/s Roll with leading side drop, 300 N Belt Tension
2024	LR	PolarII	WorldSID	Pretensioned	180 deg/s Roll, 300 N Belt Tension
2026	HR	PolarII	WorldSID	Pretensioned	360 deg/s roll, 300 N Belt Tension
2027	HR	PolarII	WorldSID	Pretensioned	360 deg/s roll, 300 N Belt Tension
2028	HRN	PolarII	WorldSID	Pretensioned	360 deg/s Roll with leading side drop, 300 N Belt Tension
2029	HRF	PolarII	WorldSID	Pretensioned	360 deg/s Roll with trailing side drop, 300 N Belt Tension
2030	LRF	PolarII	WorldSID	Nominal	180 deg/s Roll with trailing side drop, 35 N Belt Tension



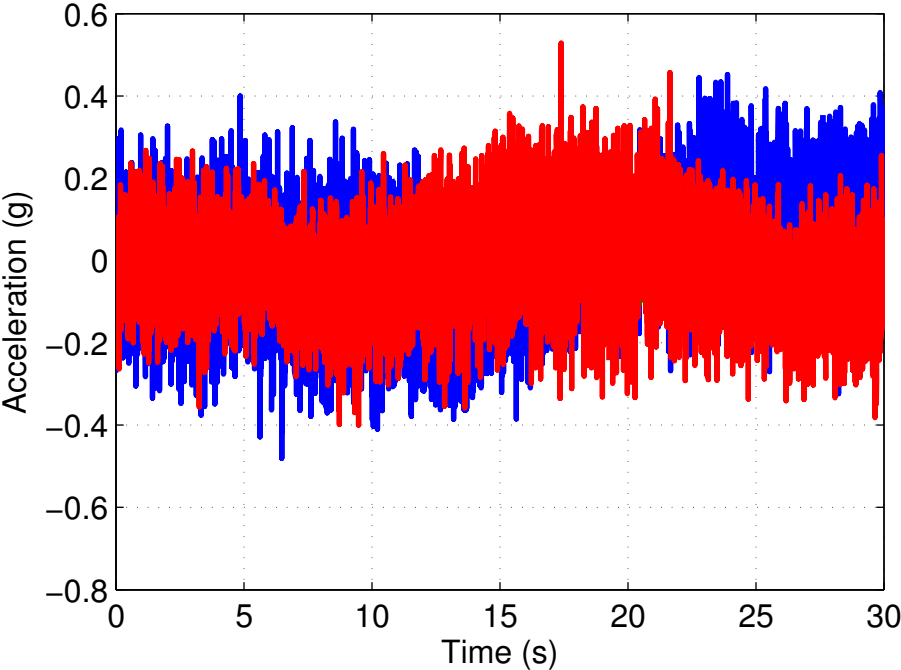
Data Set	Min (Time)	Max (Time)
AngVel-X	-3.70 (23.954)	15.75 (22.000)
AngVel-Y	-1.74 (10.544)	1.79 (2.970)
AngVel-Z	-1.84 (5.370)	1.63 (11.718)



Data Set	Min (Time)	Max (Time)
AngDisp-X	-0.11 (2.270)	183.81 (23.646)
AngDisp-Y	-5.37 (6.862)	-0.77 (29.972)
AngDisp-Z	87.38 (16.602)	90.19 (29.992)

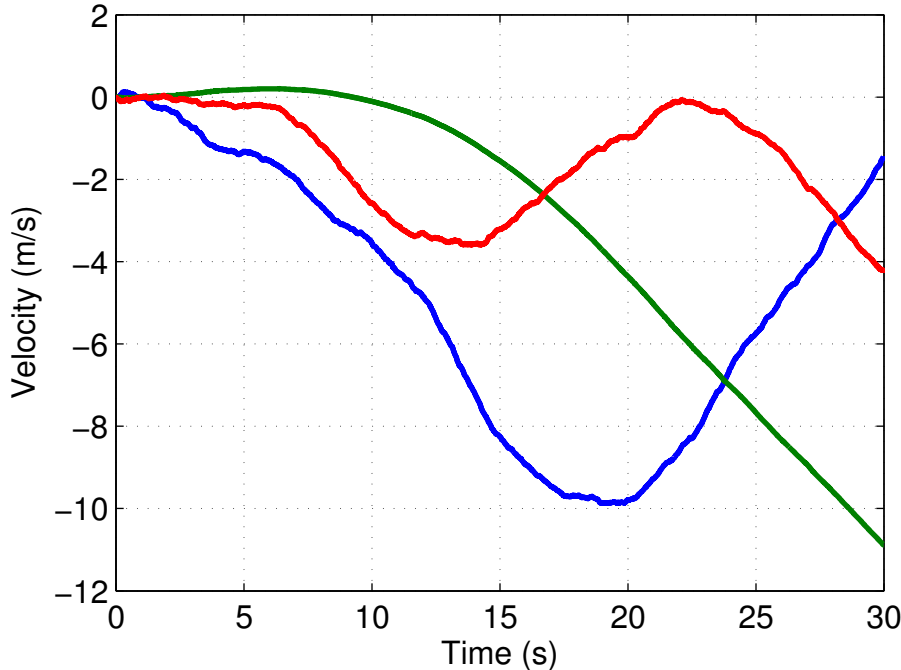


Buck CG Acceleration



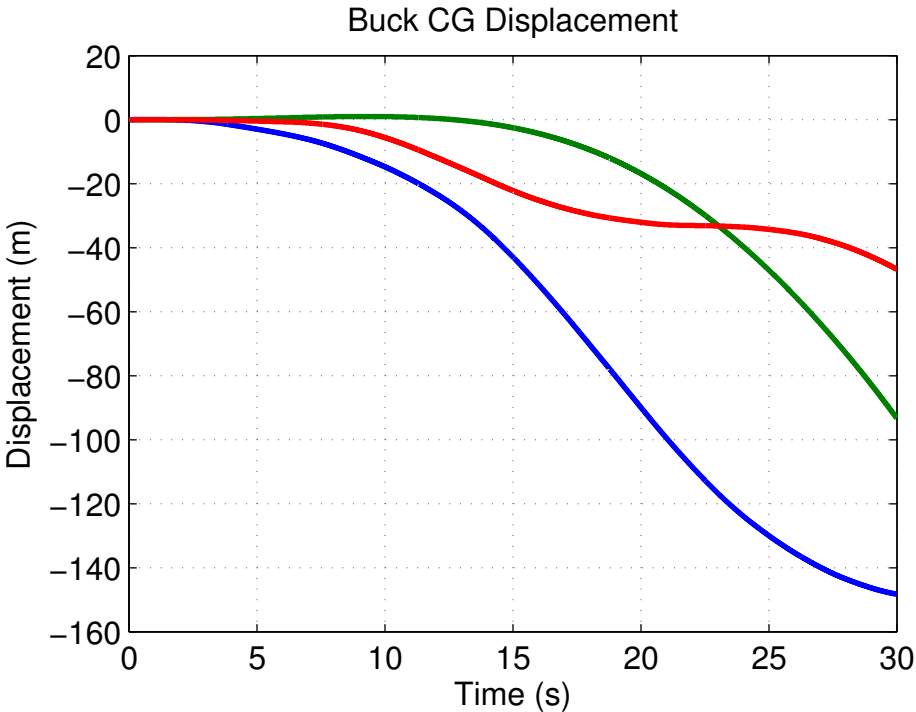
Data Set	Min (Time)	Max (Time)
Acc-X	-0.48 (6.484)	0.45 (23.896)
Acc-Y	-0.12 (21.578)	0.04 (2.542)
Acc-Z	-0.40 (9.478)	0.53 (17.392)

Buck CG Velocity

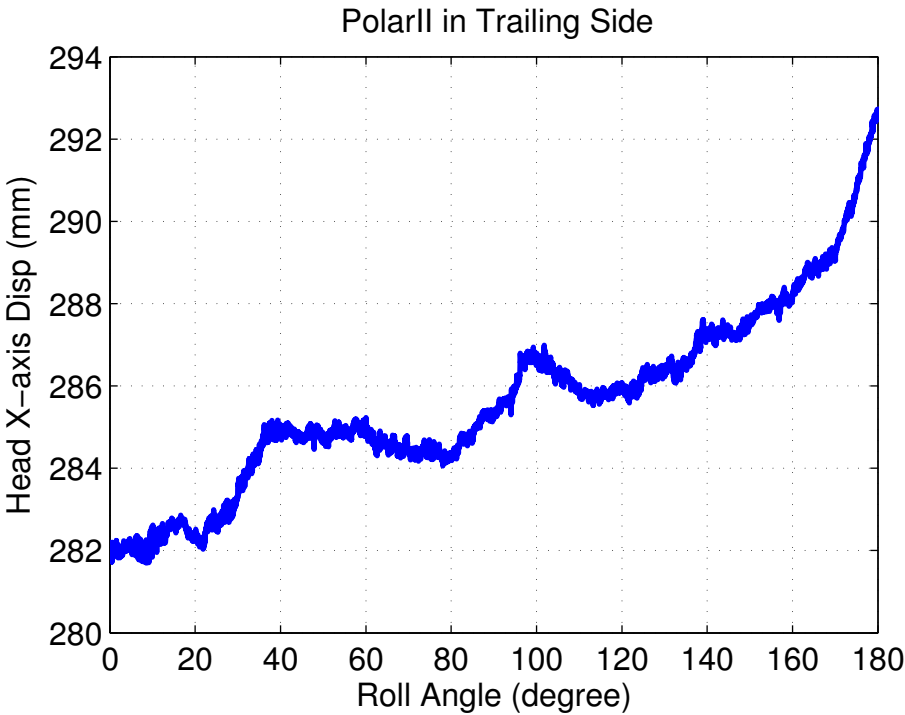


Data Set	Min (Time)	Max (Time)
Vel-X	-9.88 (19.270)	0.13 (0.344)
Vel-Y	-10.89 (29.992)	0.20 (6.384)
Vel-Z	-4.22 (29.992)	0.05 (1.888)



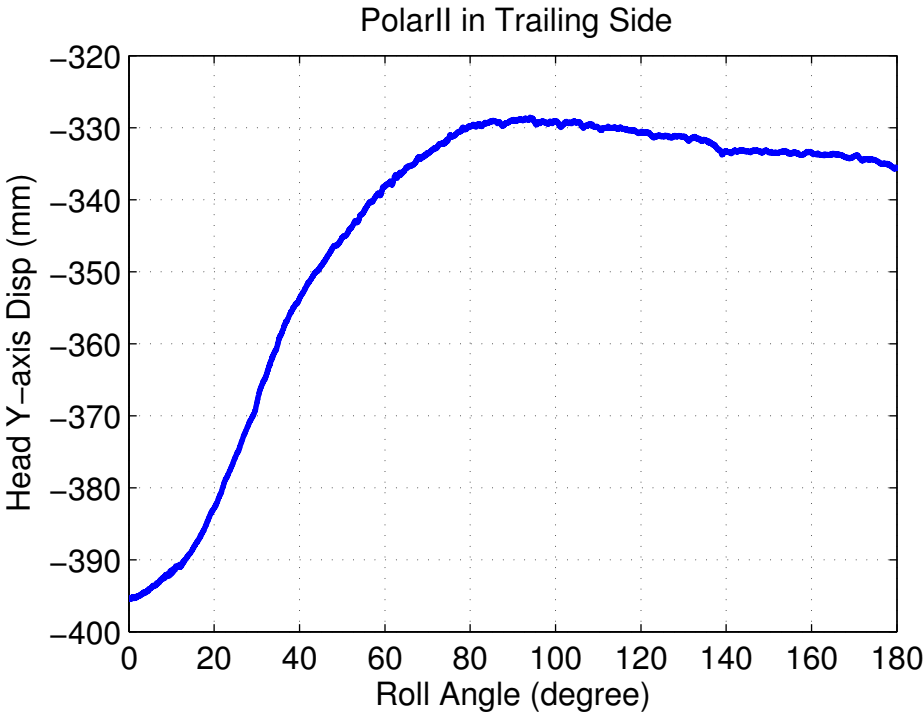


Data Set	Min (Time)	Max (Time)
Disp-X	-148.28 (29.992)	0.05 (0.850)
Disp-Y	-93.23 (29.992)	0.98 (9.234)
Disp-Z	-46.70 (29.992)	0.00 (0.000)

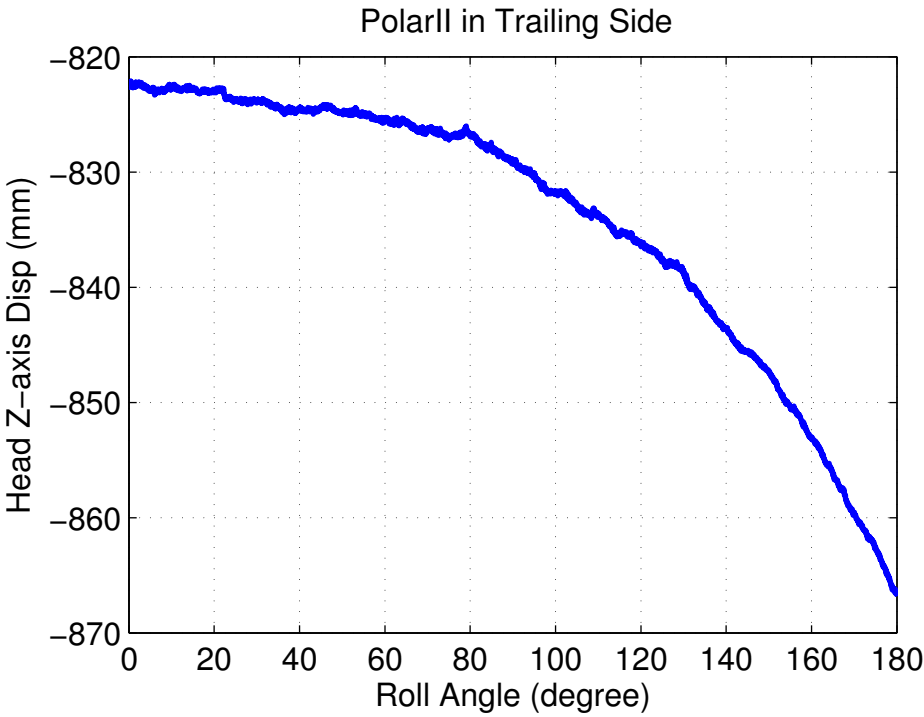


Data Set	Min Roll Ang	Max Roll Ang
Head X-axis Disp	281.70 (8.6)	294.69 (183.0)



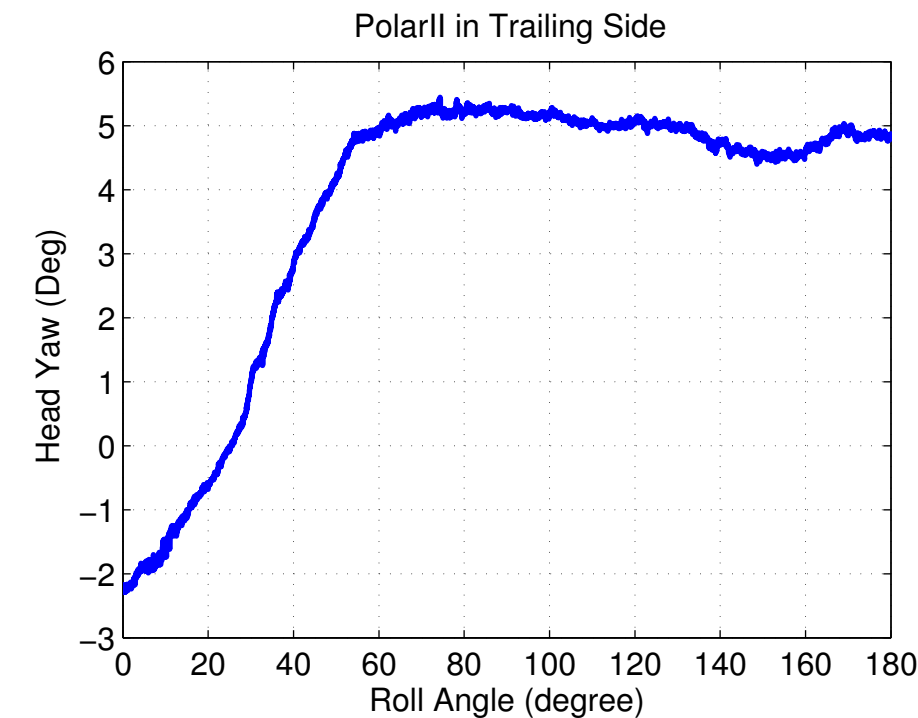


Data Set	Min Roll Ang	Max Roll Ang
Head Y-axis Disp	-395.50 (0.1)	-328.54 (94.0)

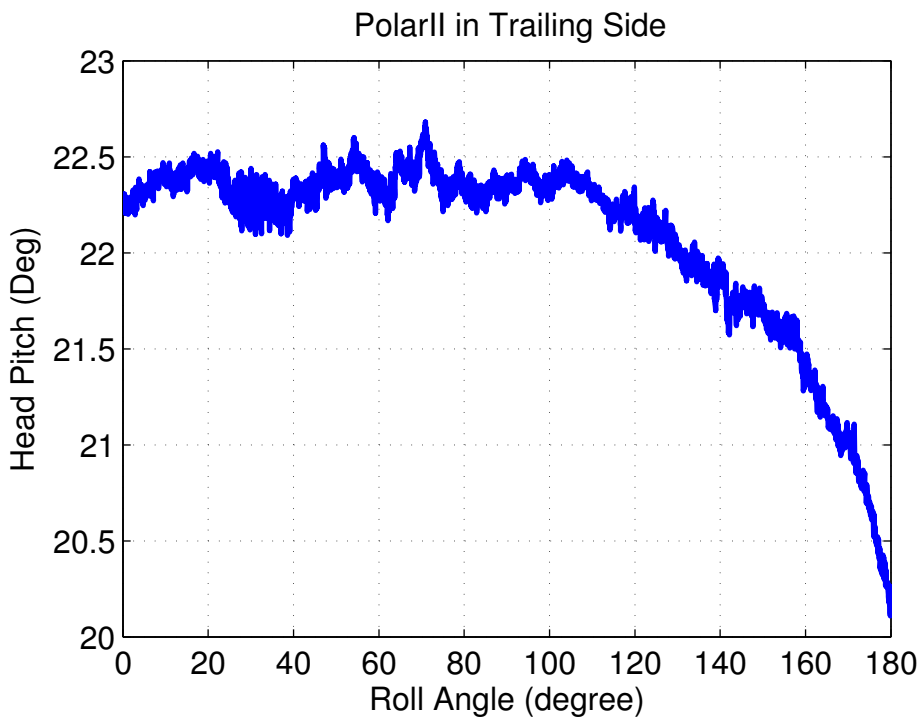


Data Set	Min Roll Ang	Max Roll Ang
Head Z-axis Disp	-870.73 (183.0)	-822.12 (0.5)



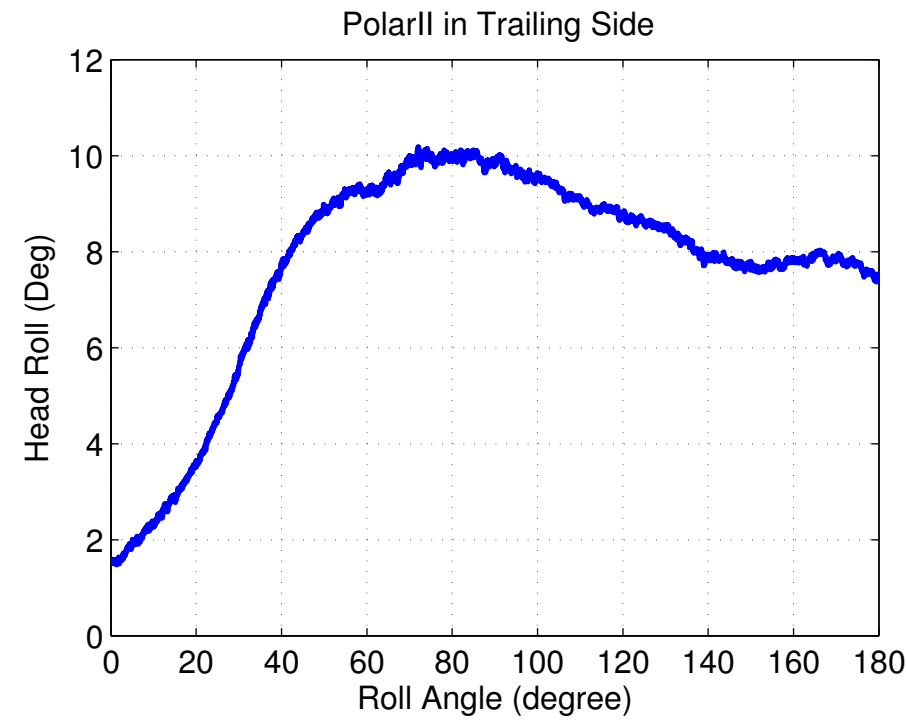


Data Set	Min Roll Ang	Max Roll Ang
Head Yaw	-2.29 (0.5)	5.44 (74.4)

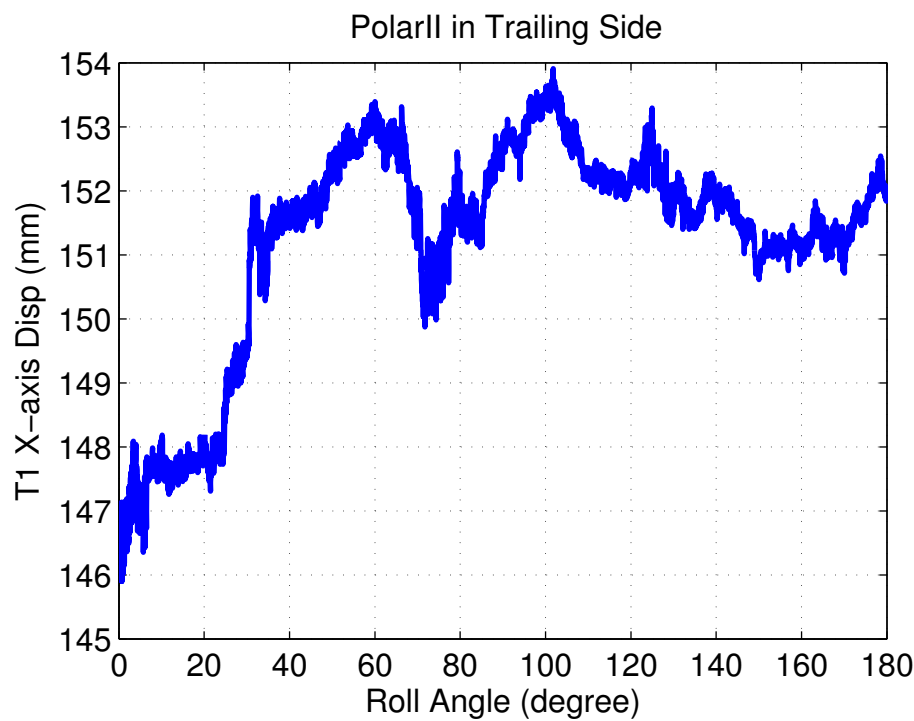


Data Set	Min Roll Ang	Max Roll Ang
Head Pitch	19.54 (183.0)	22.68 (70.9)



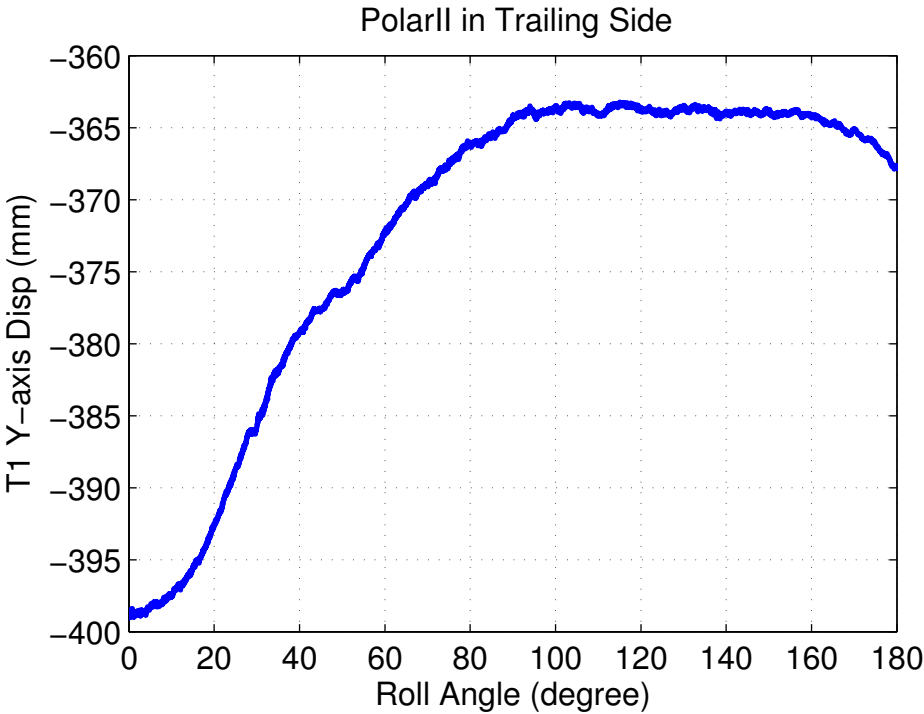


Data Set	Min Roll Ang	Max Roll Ang
Head Roll	1.48 (1.3)	10.18 (72.0)

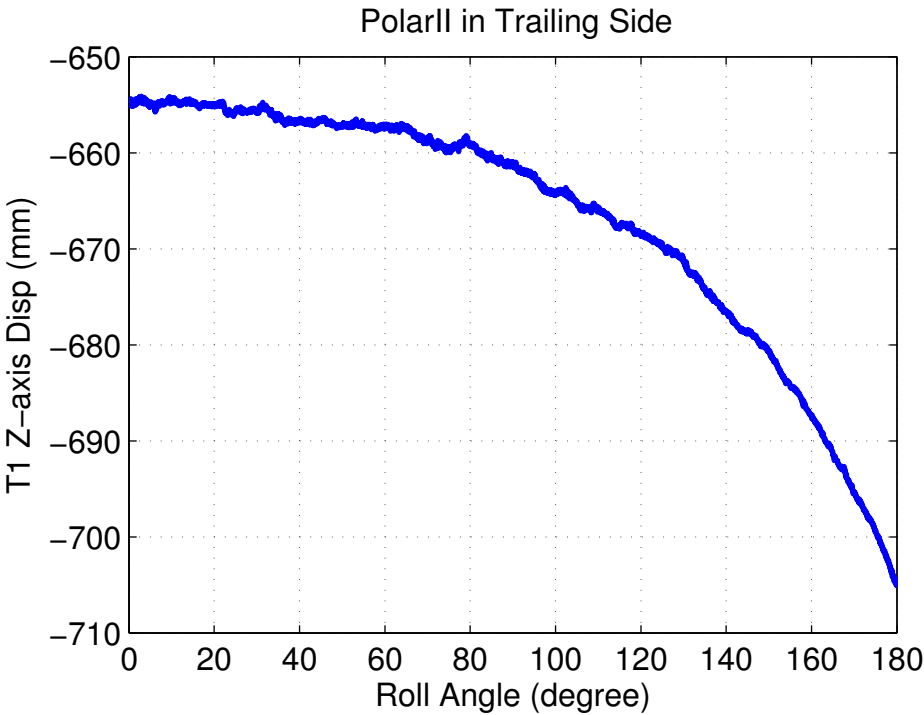


Data Set	Min Roll Ang	Max Roll Ang
T1 X-axis Disp	145.90 (0.7)	153.91 (101.8)





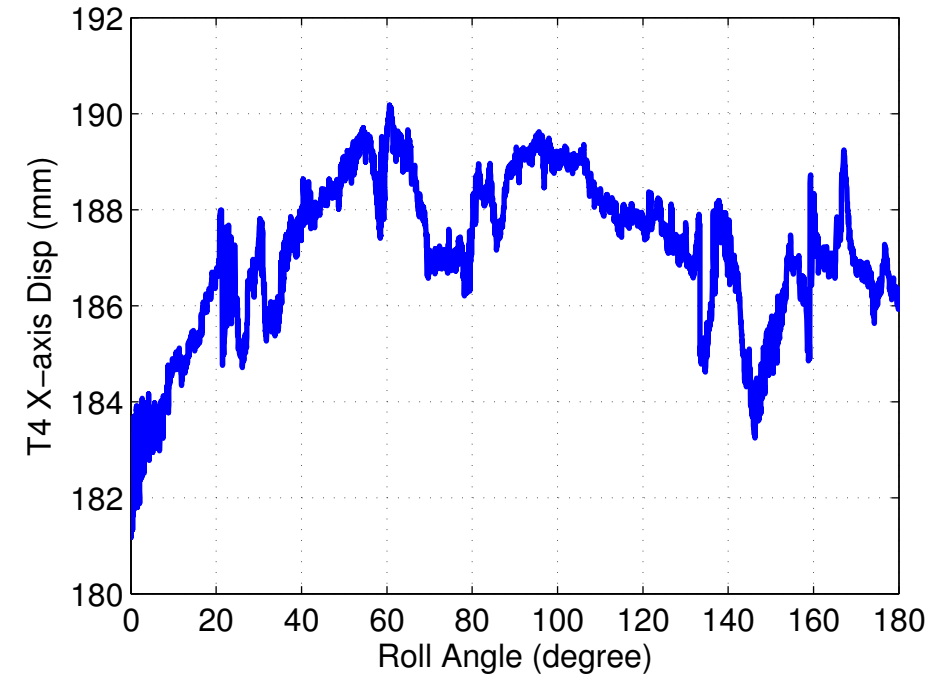
Data Set	Min Roll Ang	Max Roll Ang
T1 Y-axis Disp	-399.02 (0.1)	-363.24 (115.1)



Data Set	Min Roll Ang	Max Roll Ang
T1 Z-axis Disp	-710.73 (183.0)	-654.11 (2.9)

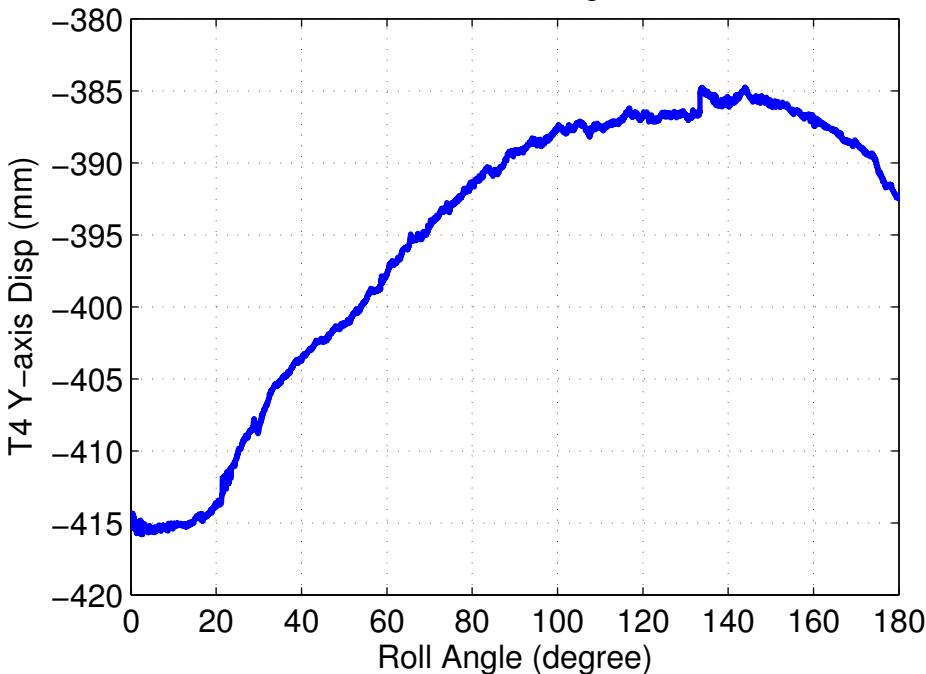


PolarII in Trailing Side



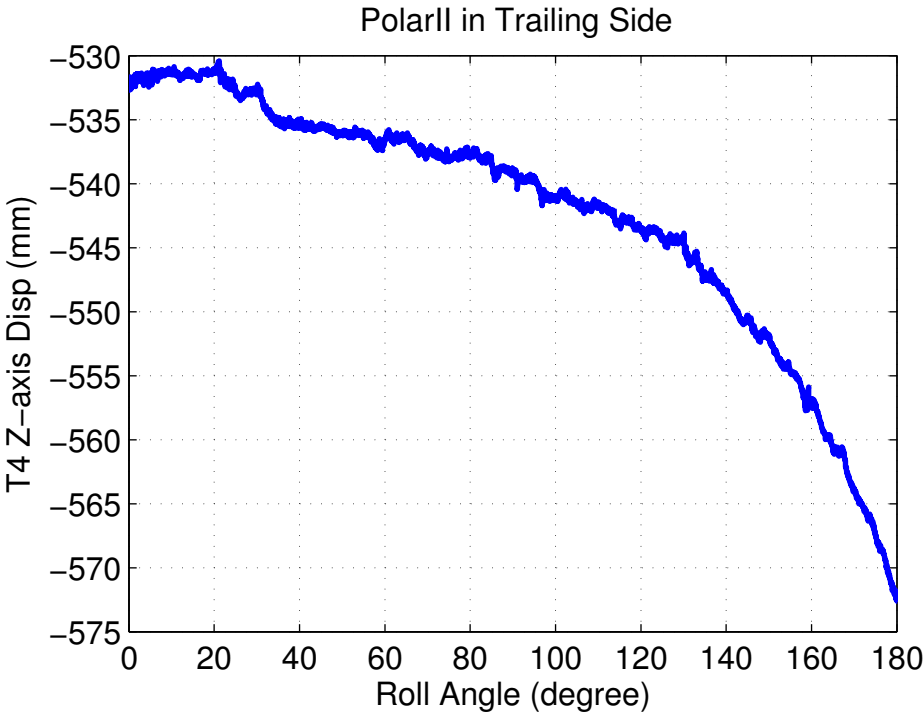
Data Set	Min	Max
	Roll Ang	Roll Ang
T4 X-axis Disp	181.17 (0.0)	190.18 (60.6)

PolarII in Trailing Side

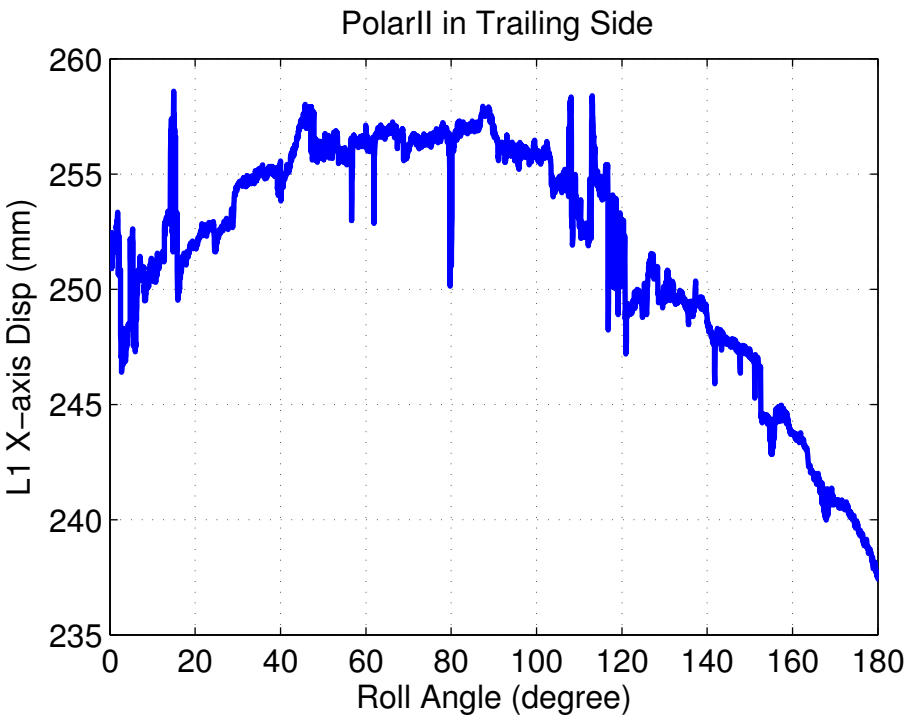


Data Set	Min	Max
	Roll Ang	Roll Ang
T4 Y-axis Disp	-415.82 (2.7)	-384.75 (144.0)



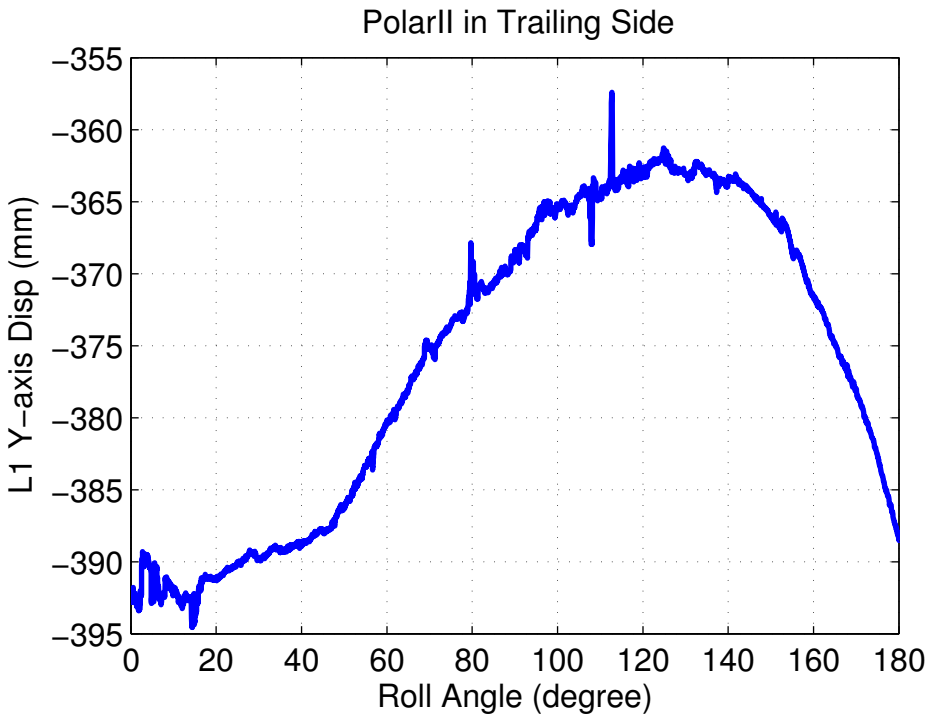


Data Set	Min Roll Ang	Max Roll Ang
T4 Z-axis Disp	-577.40 (183.0)	-530.41 (21.2)

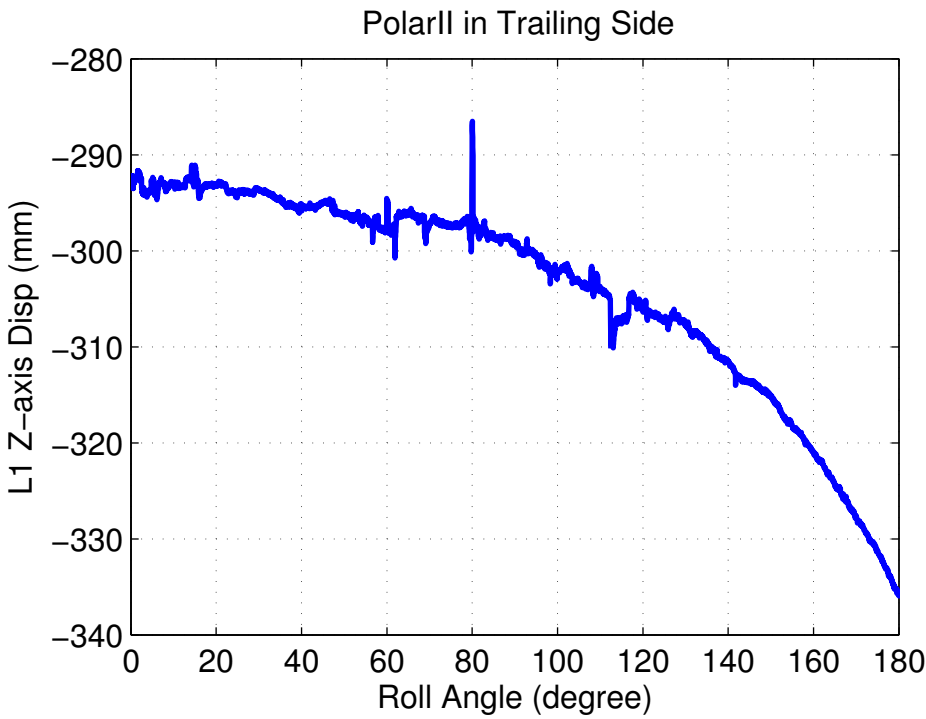


Data Set	Min Roll Ang	Max Roll Ang
L1 X-axis Disp	234.82 (183.0)	258.59 (15.0)





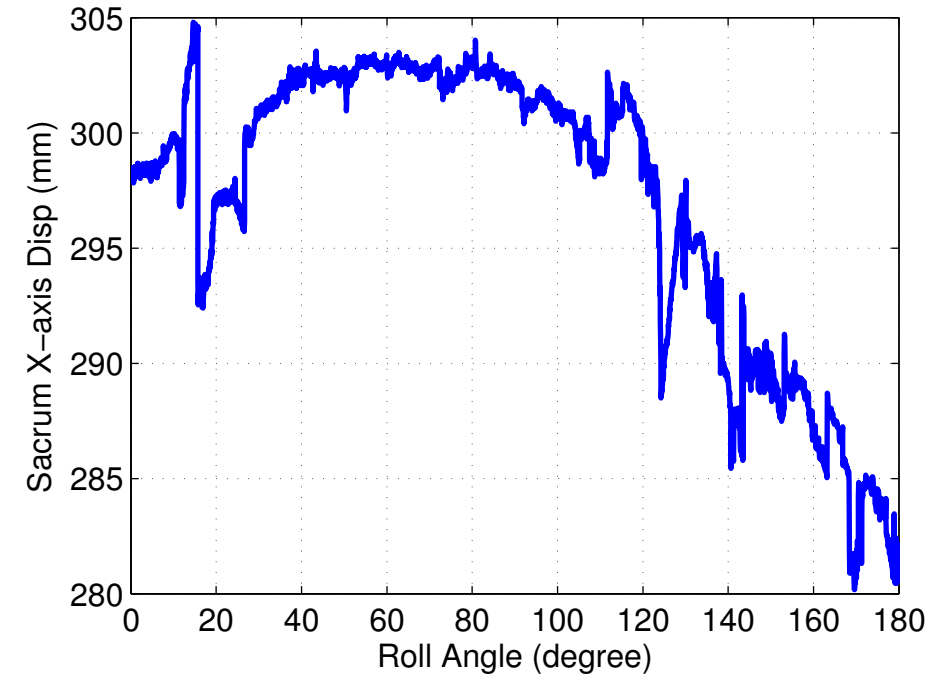
Data Set	Min	Max
	Roll Ang	Roll Ang
L1 Y-axis Disp	-394.58 (14.4)	-357.41 (112.8)



Data Set	Min	Max
	Roll Ang	Roll Ang
L1 Z-axis Disp	-340.56 (183.0)	-286.50 (80.0)

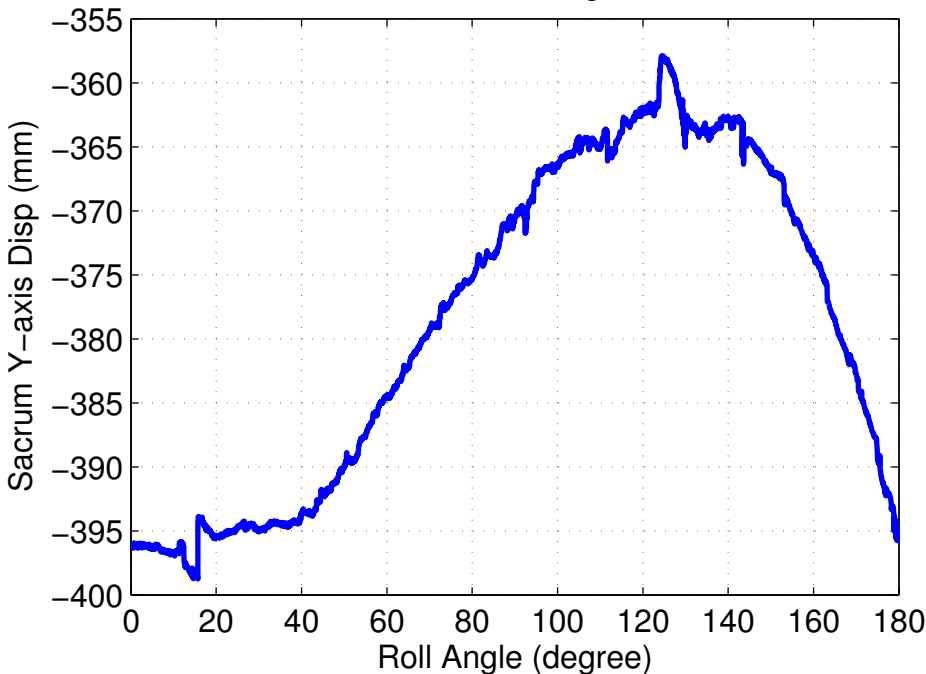


PolarII in Trailing Side



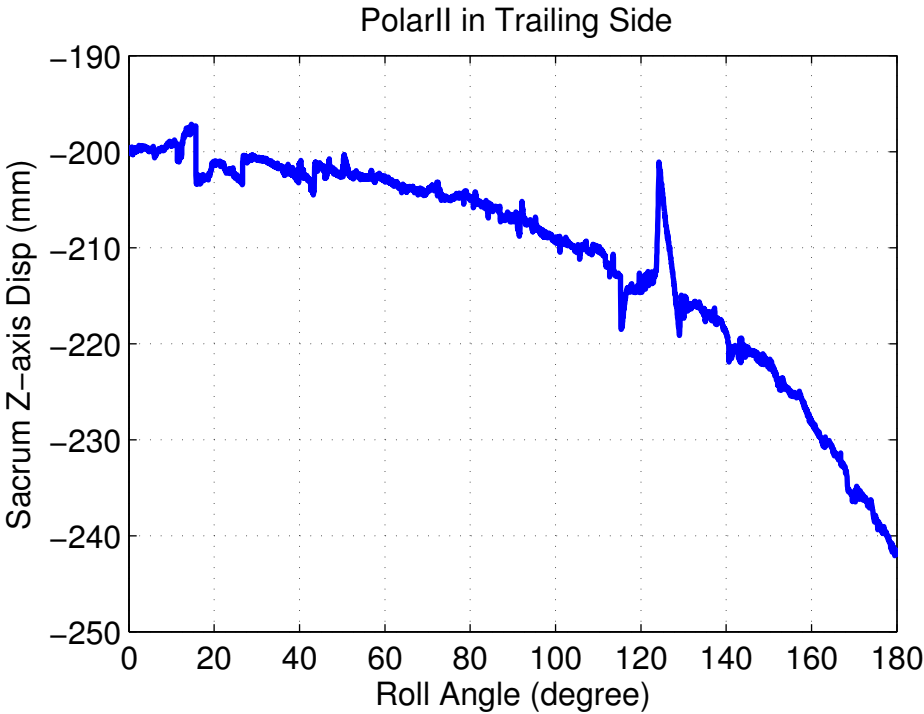
Data Set	Min	Max
	Roll Ang	Roll Ang
	277.87	304.80
Sacrum X-axis Disp	(183.0)	(14.6)

PolarII in Trailing Side

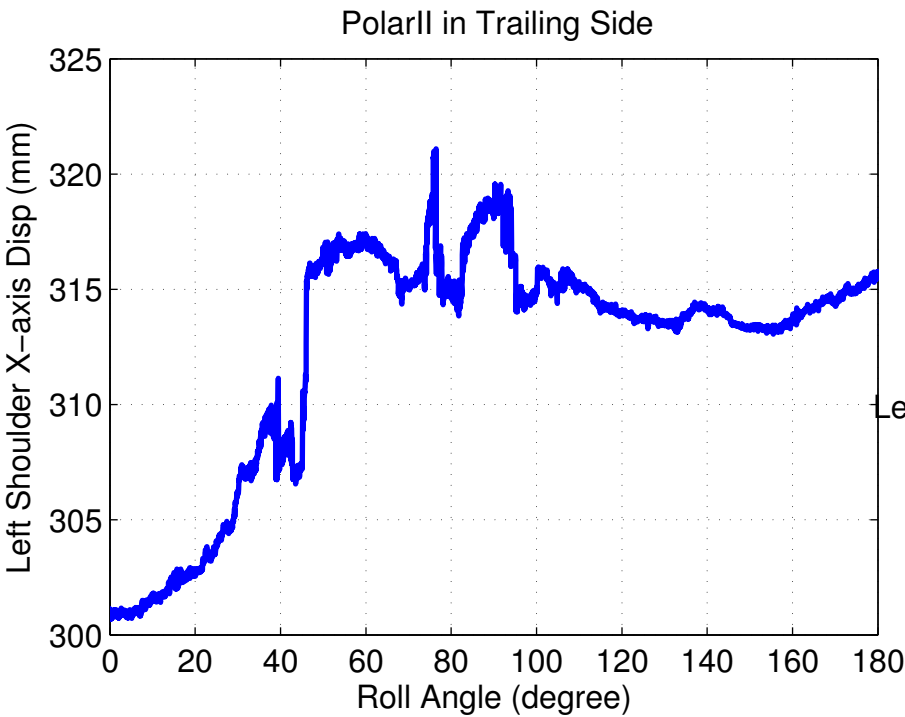


Data Set	Min	Max
	Roll Ang	Roll Ang
	-401.96	-357.90
Sacrum Y-axis Disp	(183.0)	(124.5)



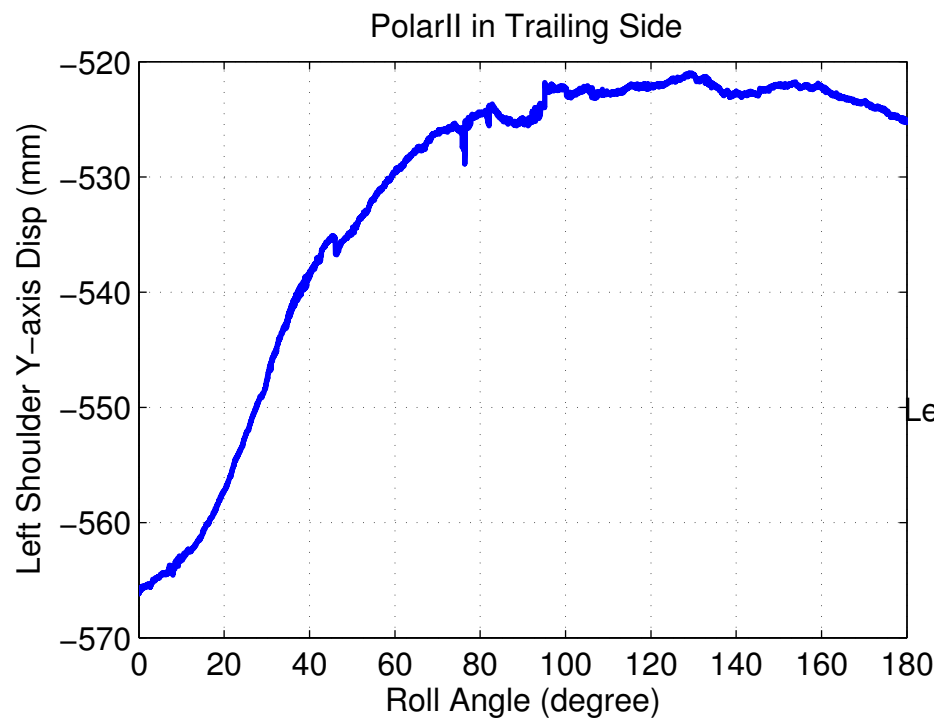


Data Set	Min Roll Ang	Max Roll Ang
Sacrum Z-axis Displacement	-246.27 (183.0)	-197.15 (14.6)

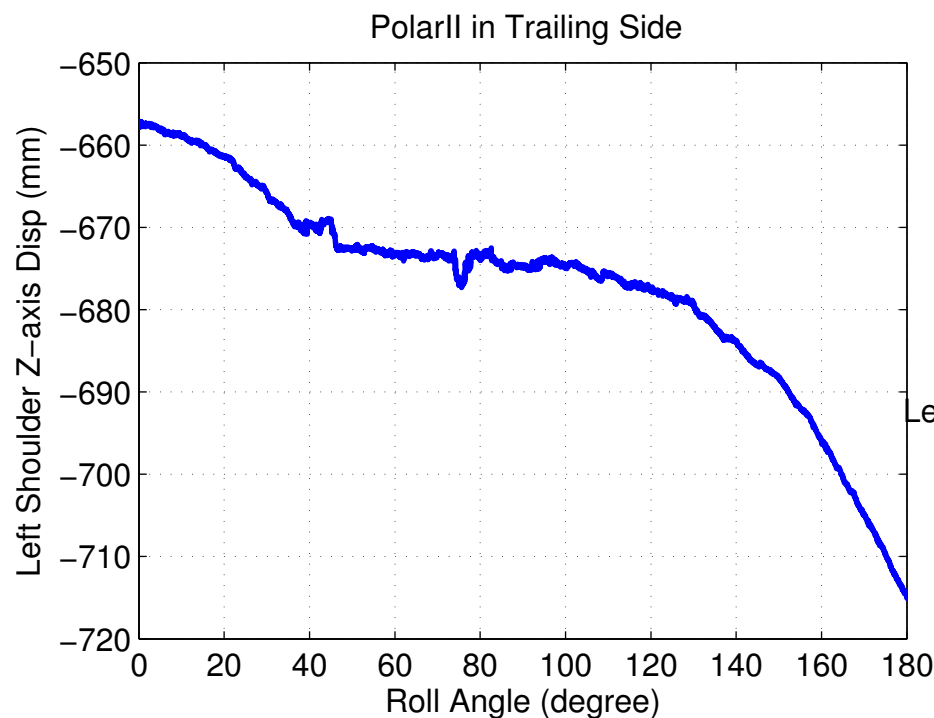


Data Set	Min Roll Ang	Max Roll Ang
Left Shoulder X-axis Displacement	300.67 (0.1)	321.09 (76.5)





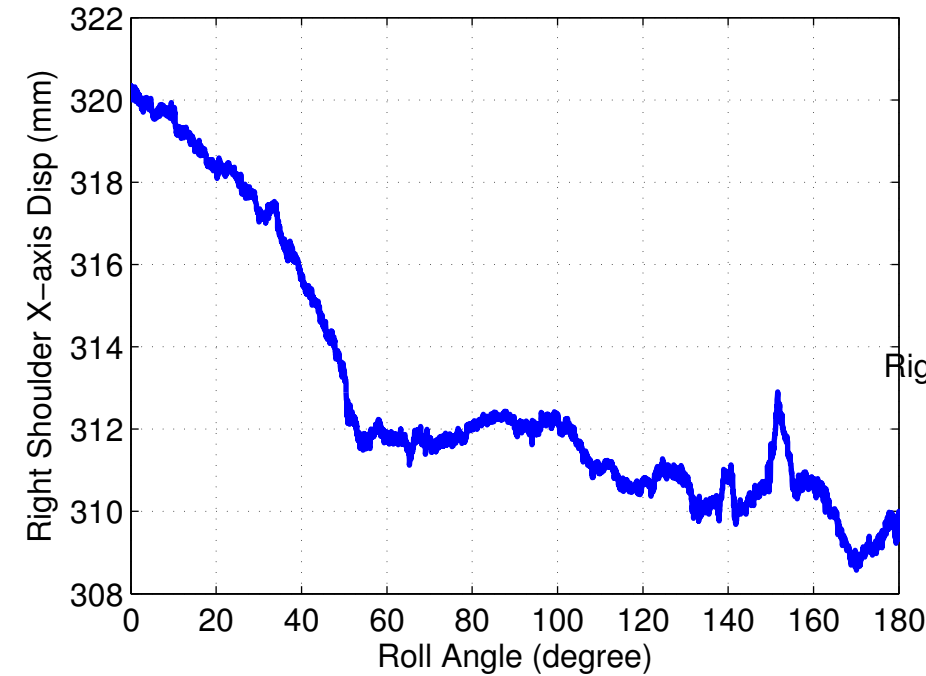
Data Set	Min	Max
	Roll Ang	Roll Ang
	-566.17 (0.0)	-520.99 (129.0)



Data Set	Min	Max
	Roll Ang	Roll Ang
	-720.71 (83.0)	-657.15 (0.5)

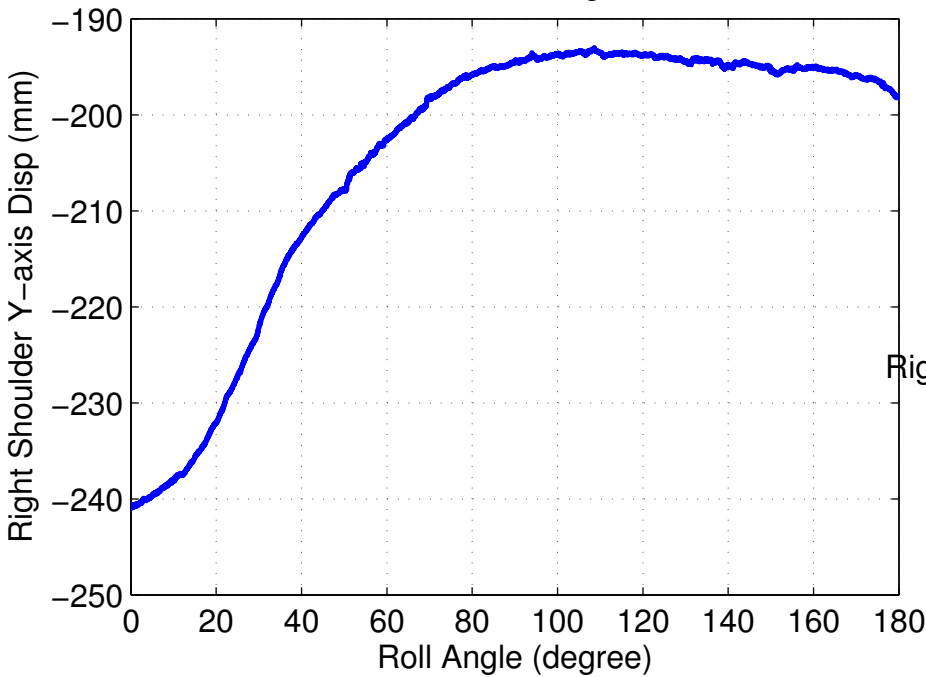


PolarII in Trailing Side



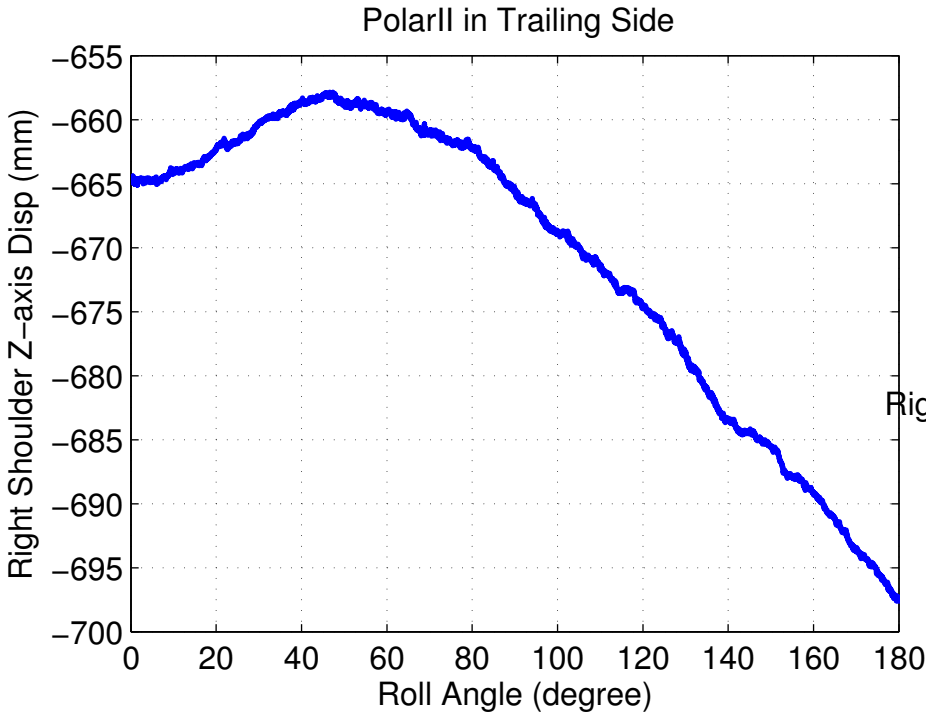
Data Set	Min	Max
	Roll Ang	Roll Ang
Right Shoulder X-axis Displacement	308.57 (170.1)	320.35 (0.0)

PolarII in Trailing Side

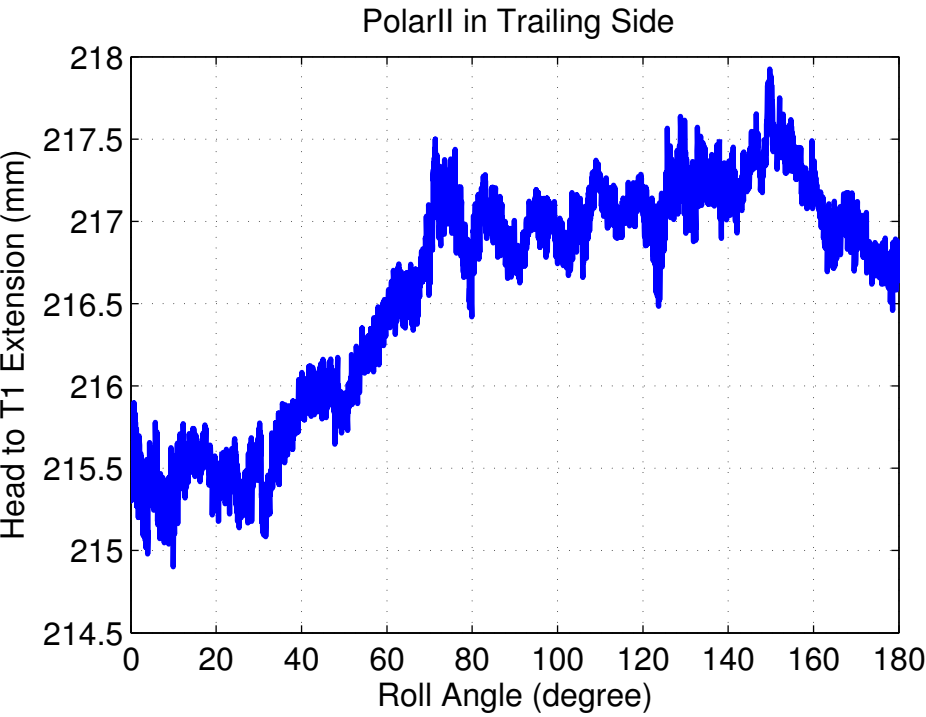


Data Set	Min	Max
	Roll Ang	Roll Ang
Right Shoulder Y-axis Displacement	-240.94 (0.0)	-193.03 (108.6)



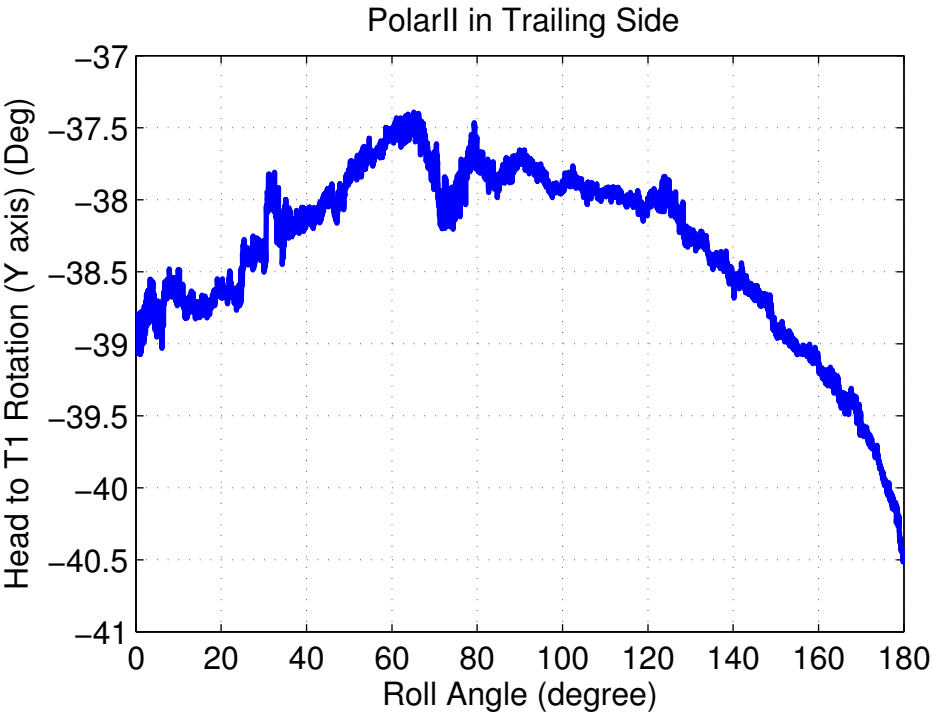


Data Set	Min Roll Ang	Max Roll Ang
Right Shoulder Z-axis Displacement	-699.77 (13.0)	-657.87 (46.6)

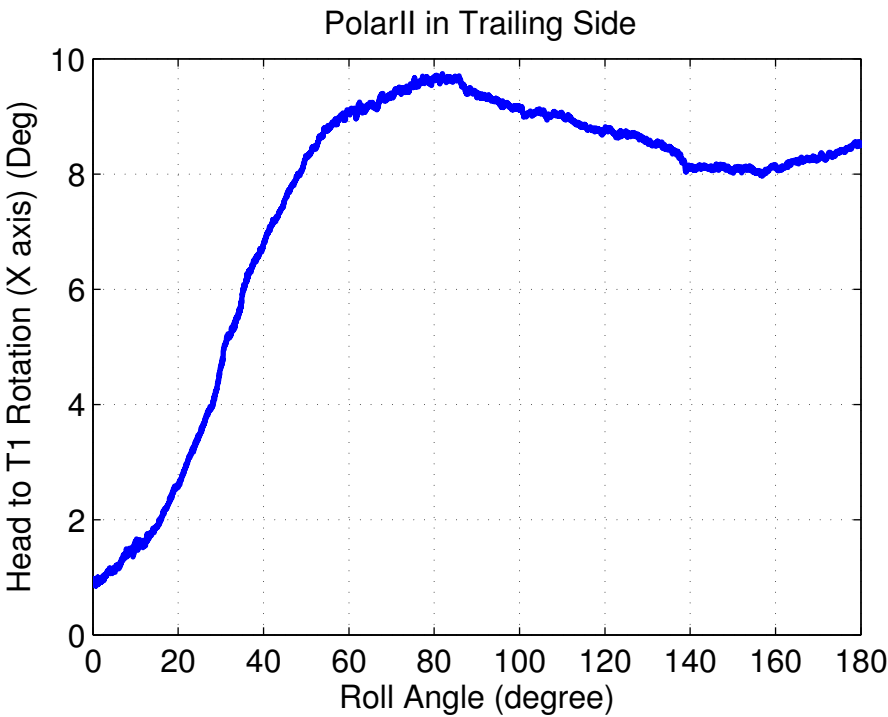


Data Set	Min Roll Ang	Max Roll Ang
Head to T1 Extension	214.90 (10.0)	217.92 (149.8)





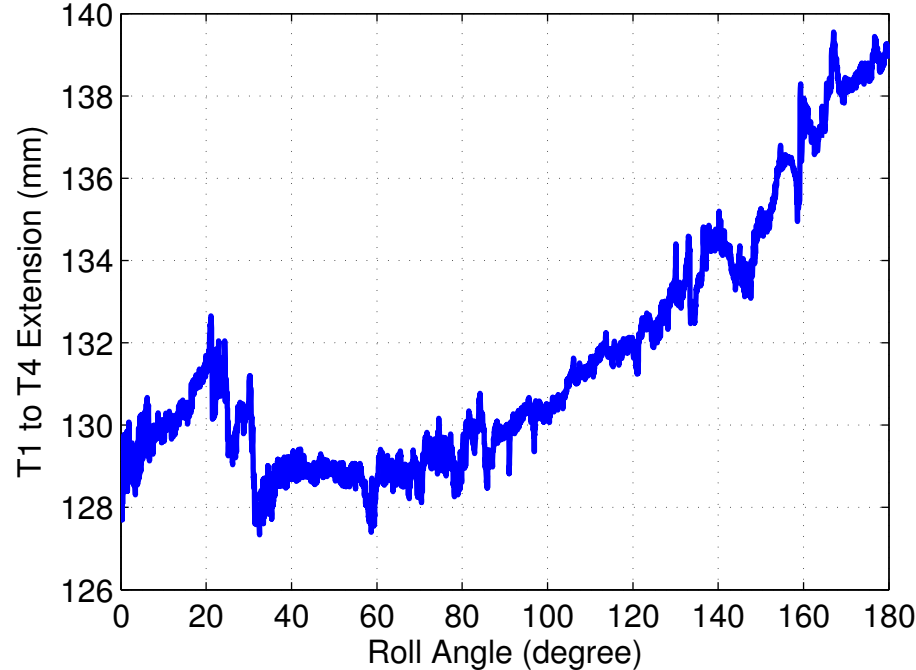
Data Set	Min Roll Ang	Max Roll Ang
Head to T1 Rotation	-41.11 (182.9)	-37.39 (65.2)



Data Set	Min Roll Ang	Max Roll Ang
Head to T1 Rotation	0.85 (0.7)	9.74 (82.0)

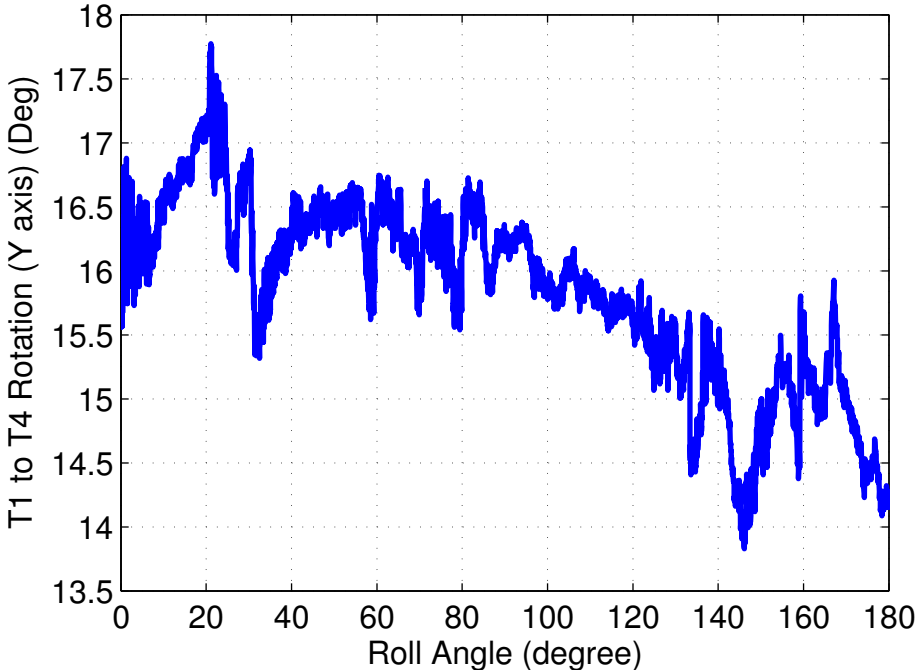


PolarII in Trailing Side



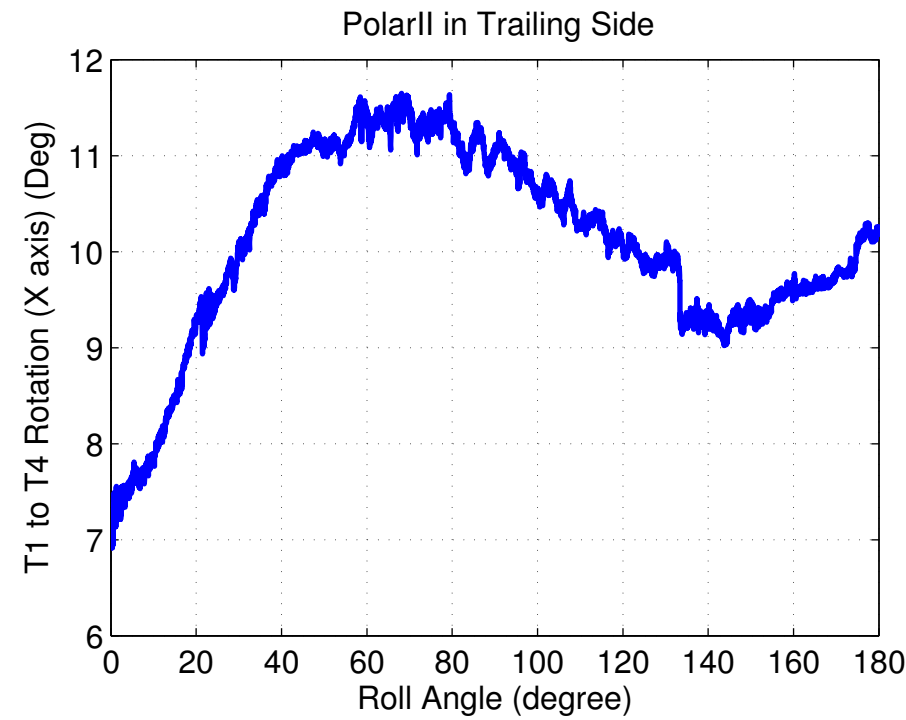
Data Set	Min Roll Ang	Max Roll Ang
T1 to T4 Extension	127.33 (32.5)	140.21 (181.8)

PolarII in Trailing Side

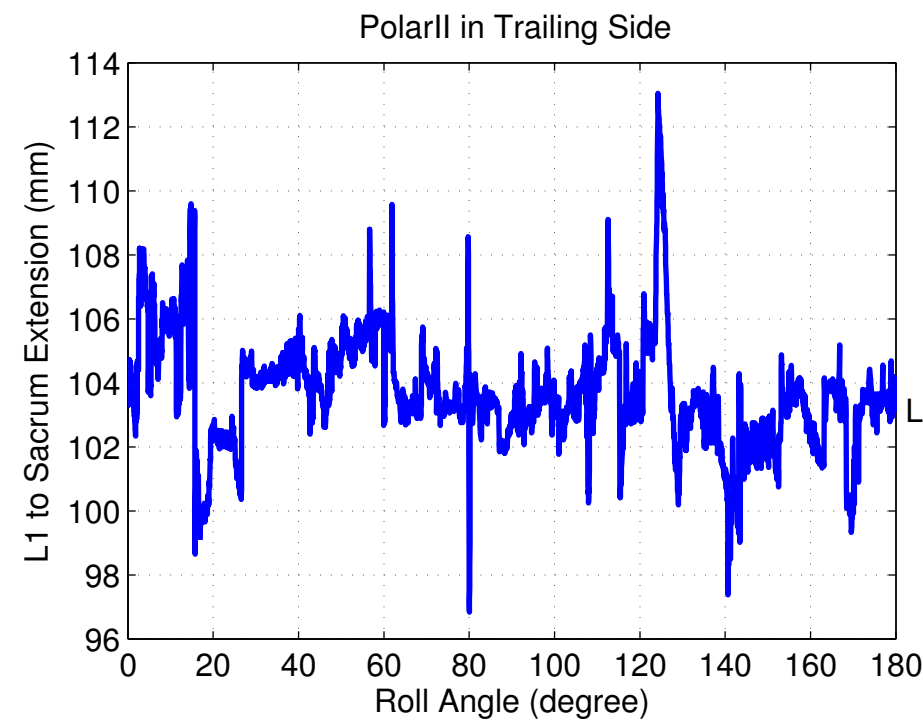


Data Set	Min Roll Ang	Max Roll Ang
T1 to T4 Rotation	13.78 (182.8)	17.77 (21.1)



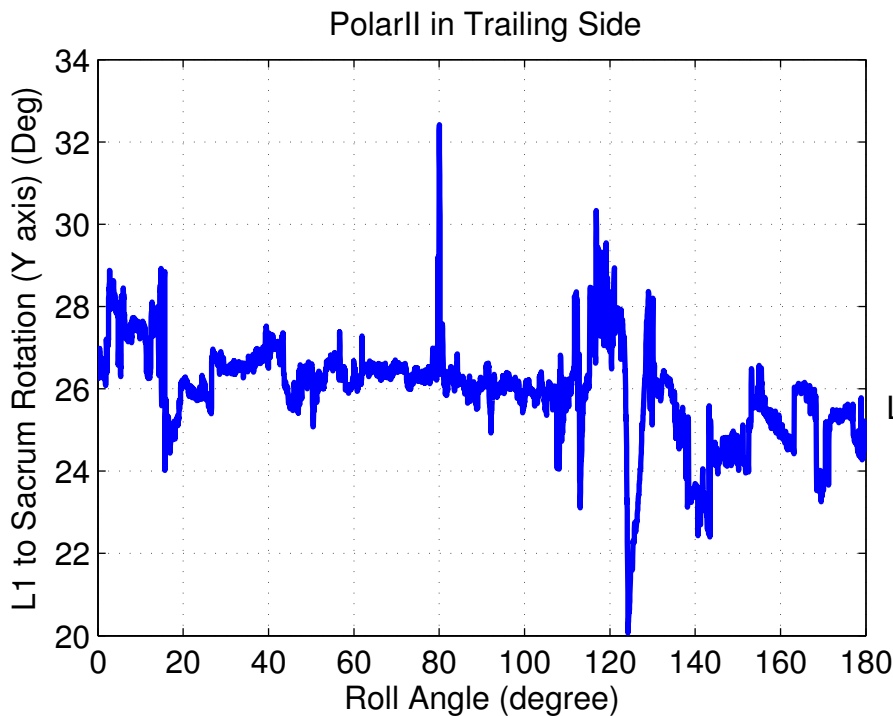


Data Set	Min Roll Ang	Max Roll Ang
T1 to T4 Rotation	6.92 (0.3)	11.65 (68.1)

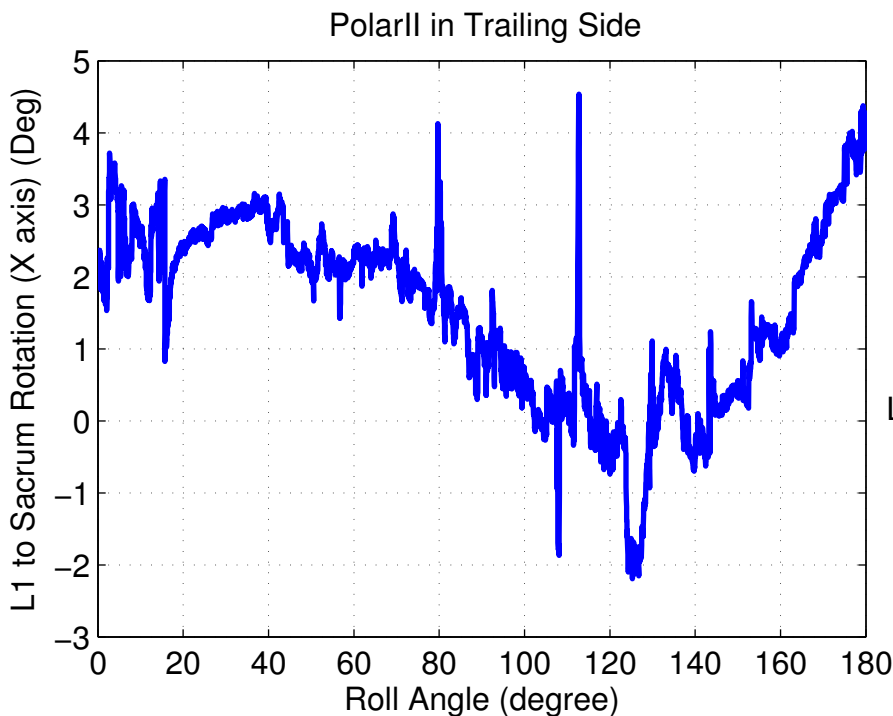


Data Set	Min Roll Ang	Max Roll Ang
L1 to Sacrum Extension	96.83 (80.0)	113.05 (124.2)





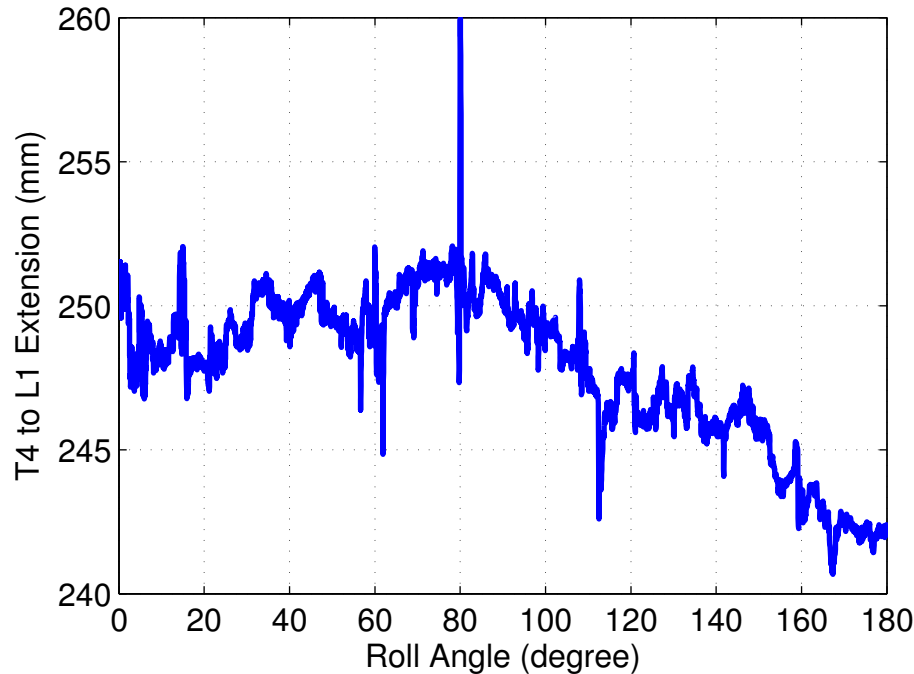
Data Set	Min Roll Ang	Max Roll Ang
	20.07 (124.2)	32.42 (80.0)



Data Set	Min Roll Ang	Max Roll Ang
	-2.19 (125.3)	5.10 (183.0)

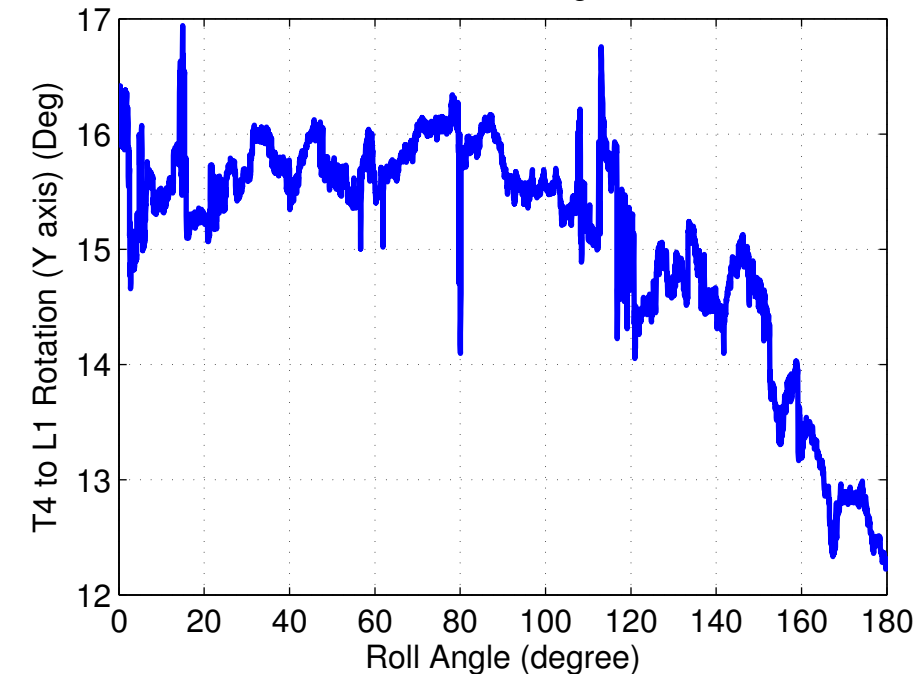


PolarII in Trailing Side



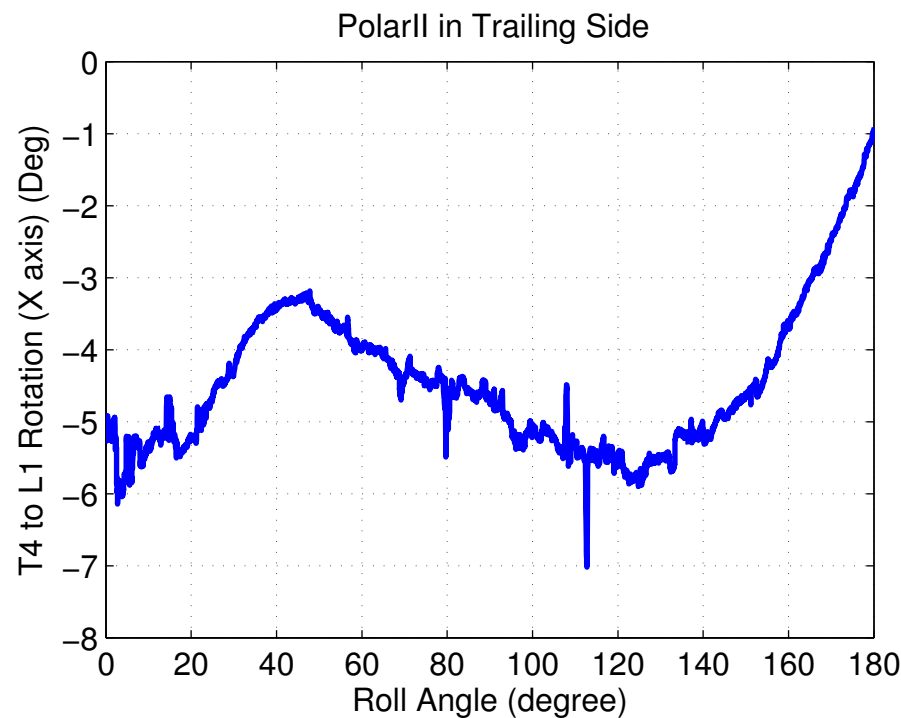
Data Set	Min Roll Ang	Max Roll Ang
T4 to L1 Extension	240.67 (167.4)	259.97 (80.0)

PolarII in Trailing Side

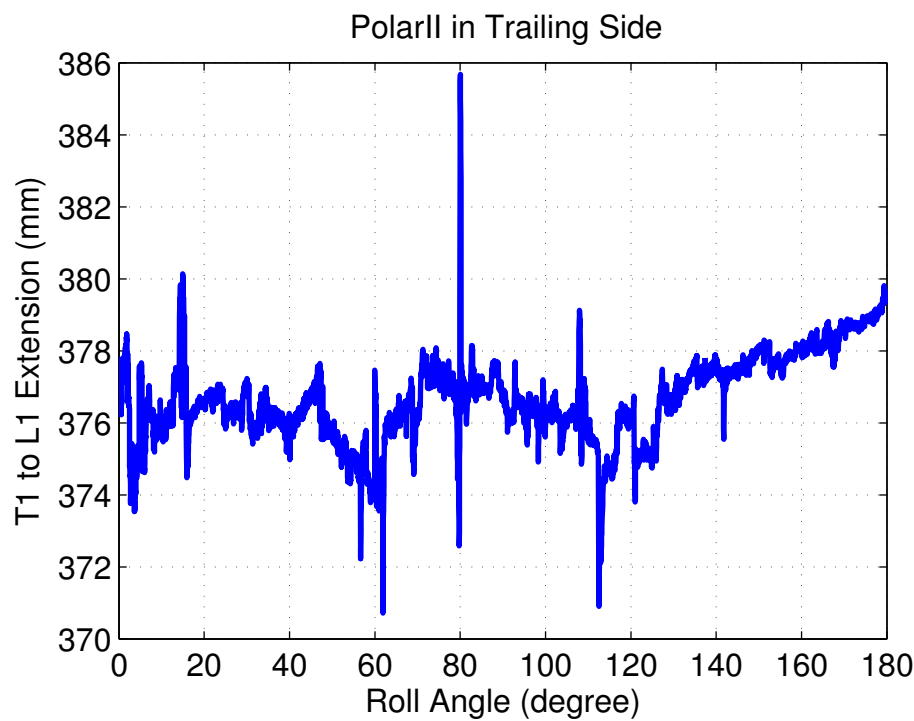


Data Set	Min Roll Ang	Max Roll Ang
T4 to L1 Rotation	11.74 (182.9)	16.94 (15.0)



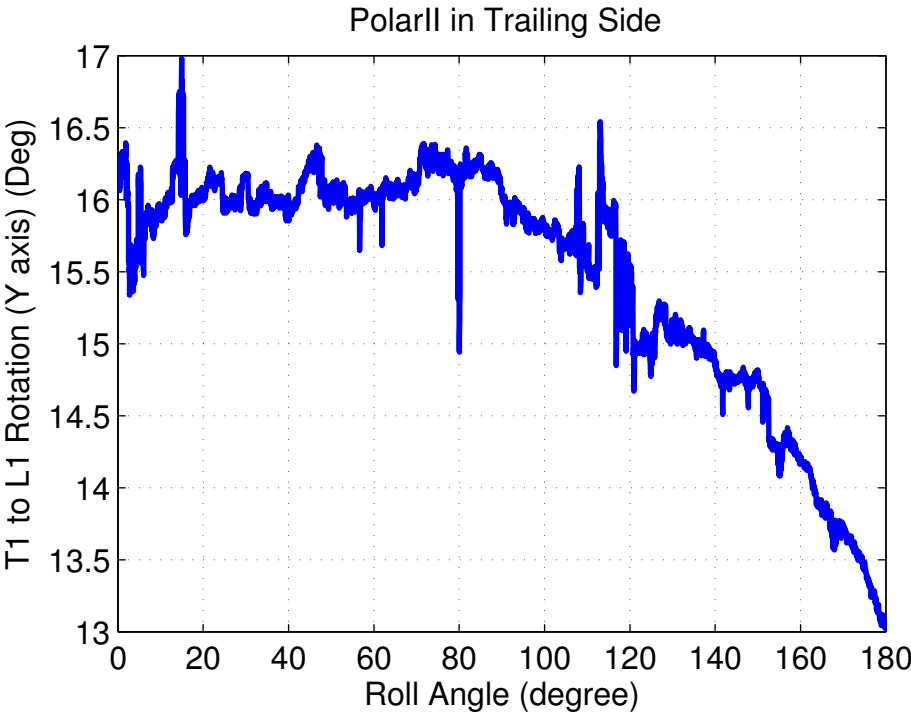


Data Set	Min Roll Ang	Max Roll Ang
T4 to L1 Rotation	-7.02 (112.8)	-0.41 (182.7)

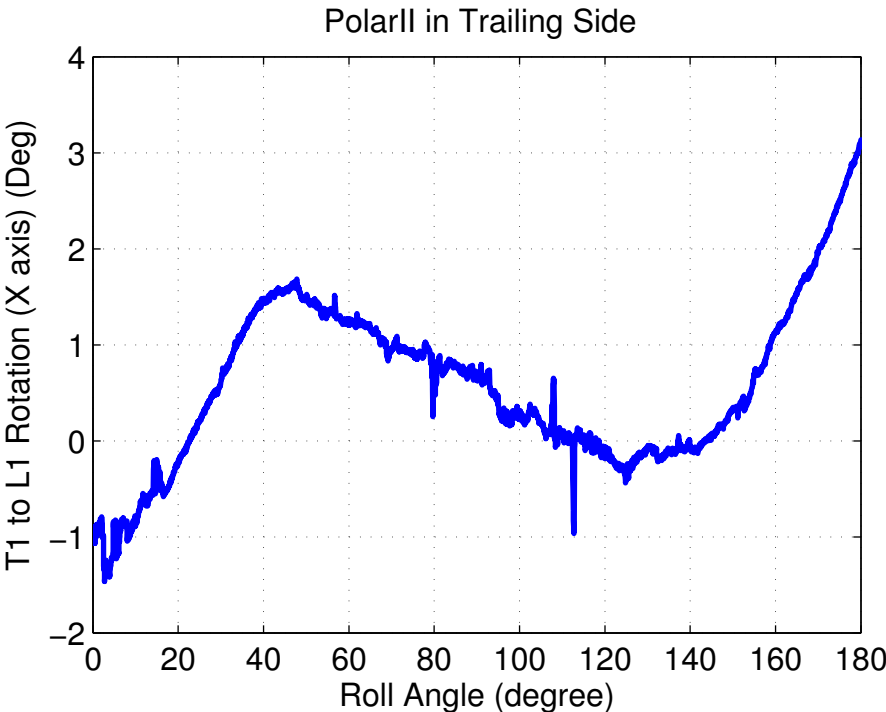


Data Set	Min Roll Ang	Max Roll Ang
T1 to L1 Extension	370.71 (61.9)	385.68 (80.0)



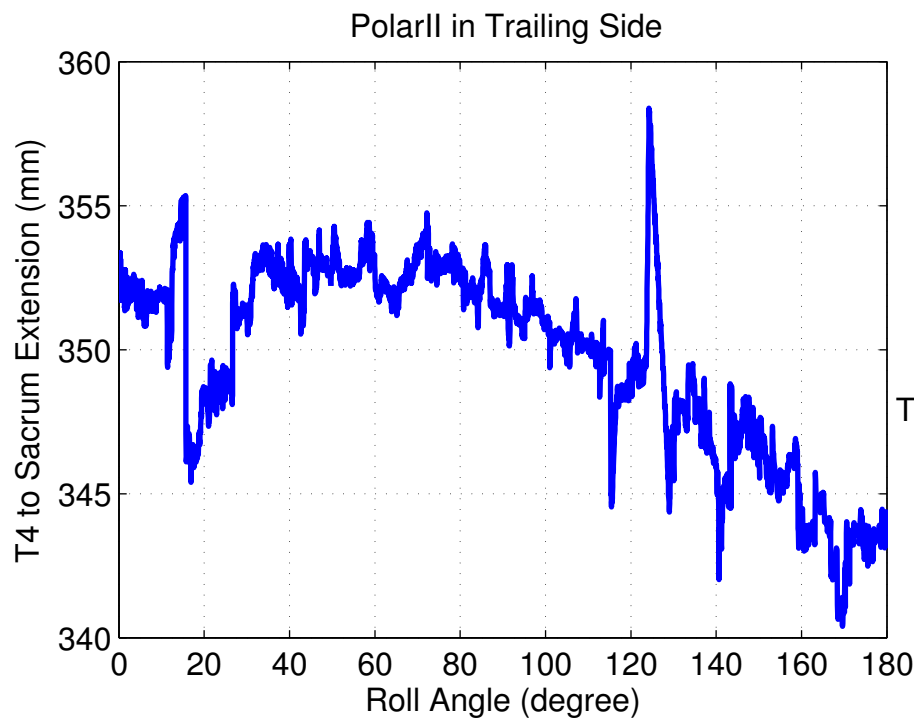


Data Set	Min Roll Ang	Max Roll Ang
T1 to L1 Rotation	12.56 (183.0)	16.98 (15.0)

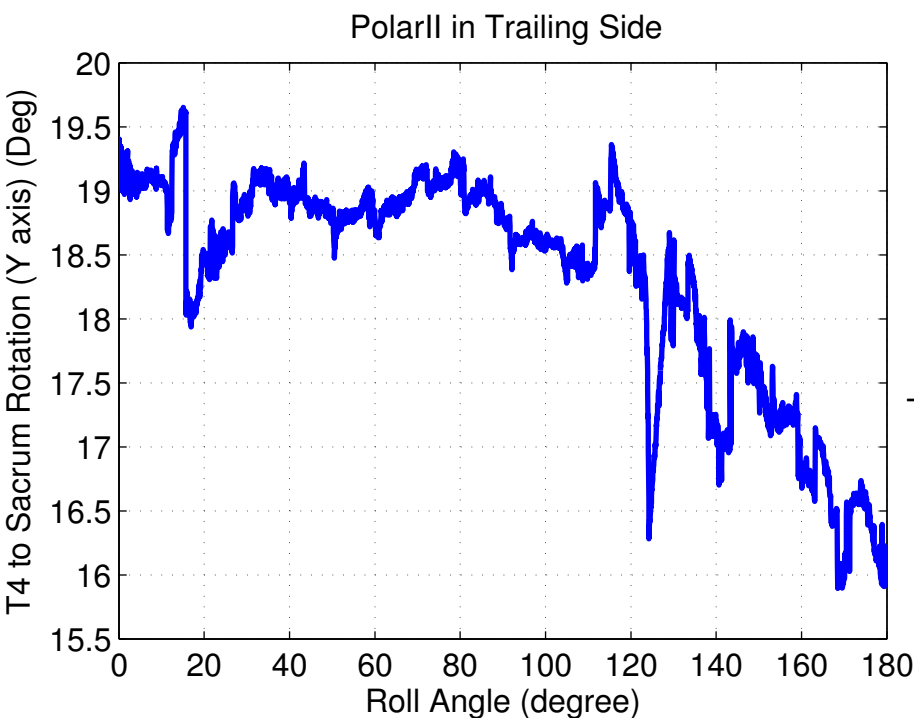


Data Set	Min Roll Ang	Max Roll Ang
T1 to L1 Rotation	-1.46 (2.7)	3.58 (182.9)



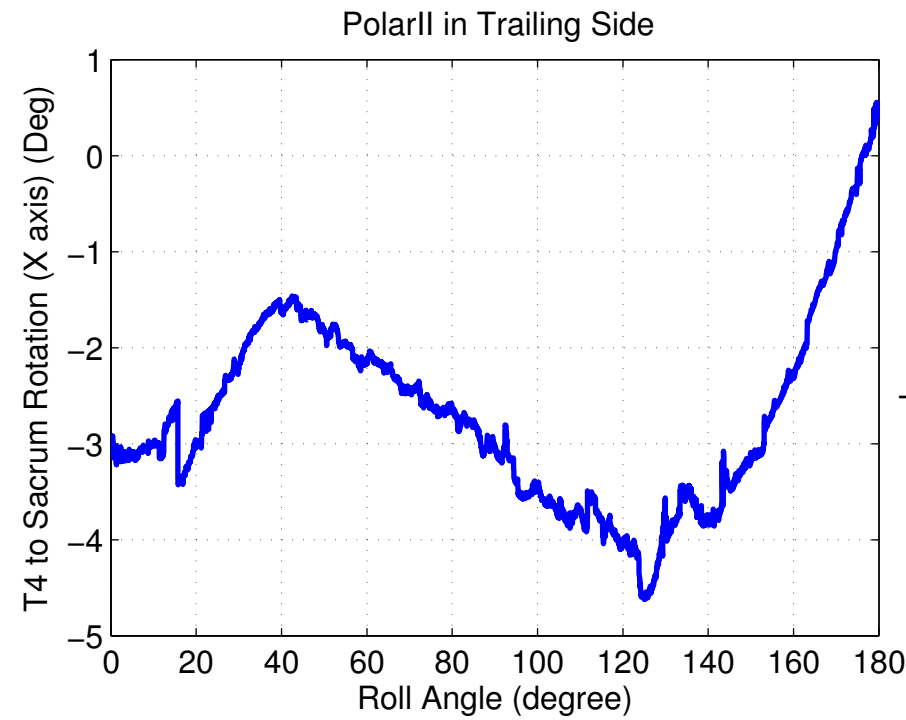


Data Set	Min	Max
	Roll Ang	Roll Ang
	340.39 (169.6)	358.39 (124.2)

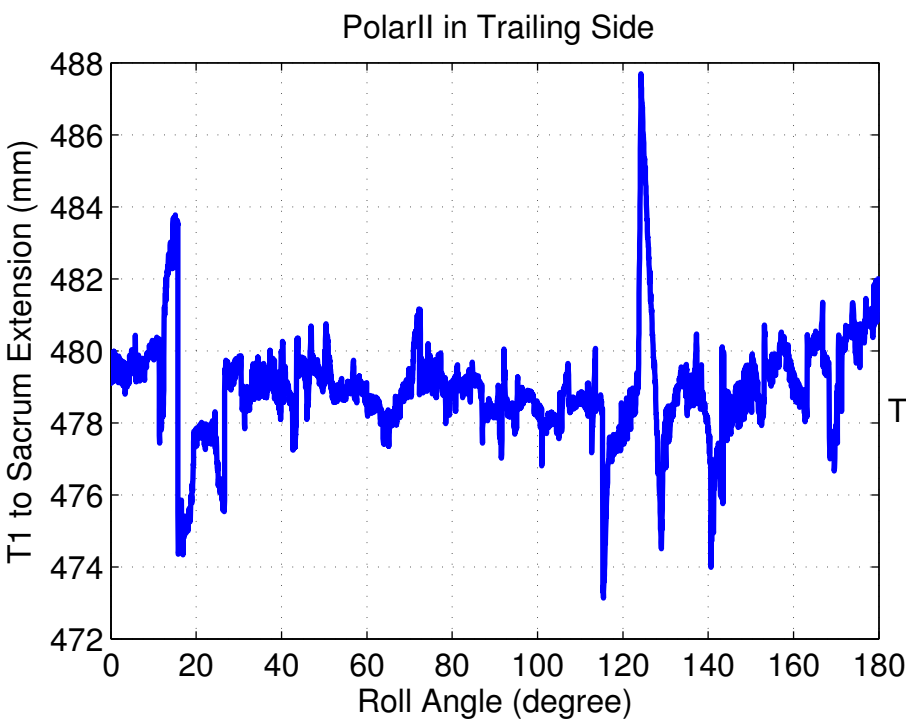


Data Set	Min	Max
	Roll Ang	Roll Ang
	15.56 (183.0)	19.65 (15.1)



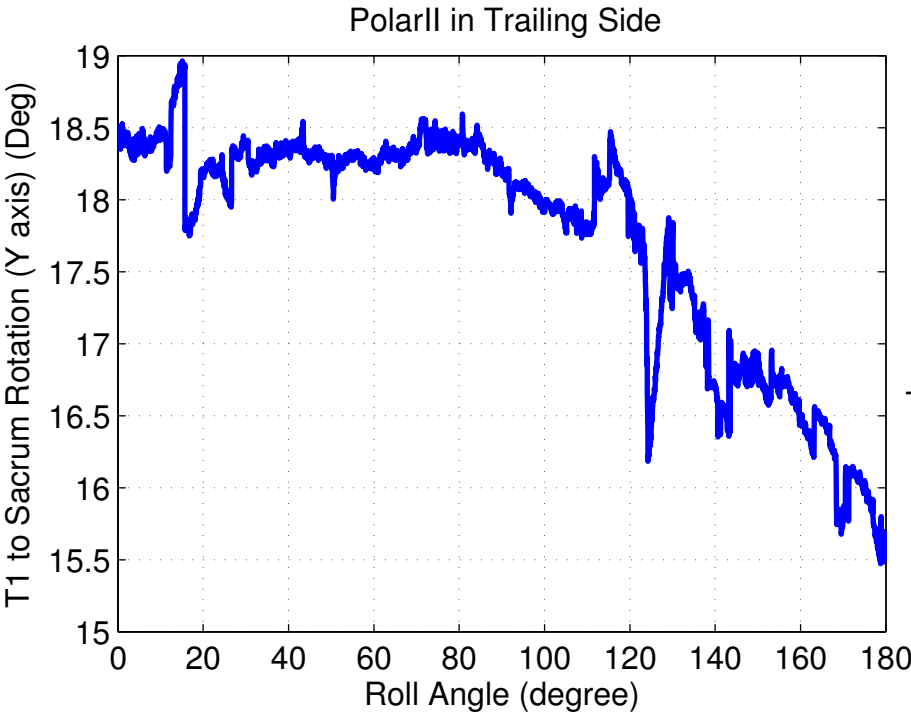


Data Set	Min Roll Ang	Max Roll Ang
	-4.62 (125.0)	1.23 (183.0)

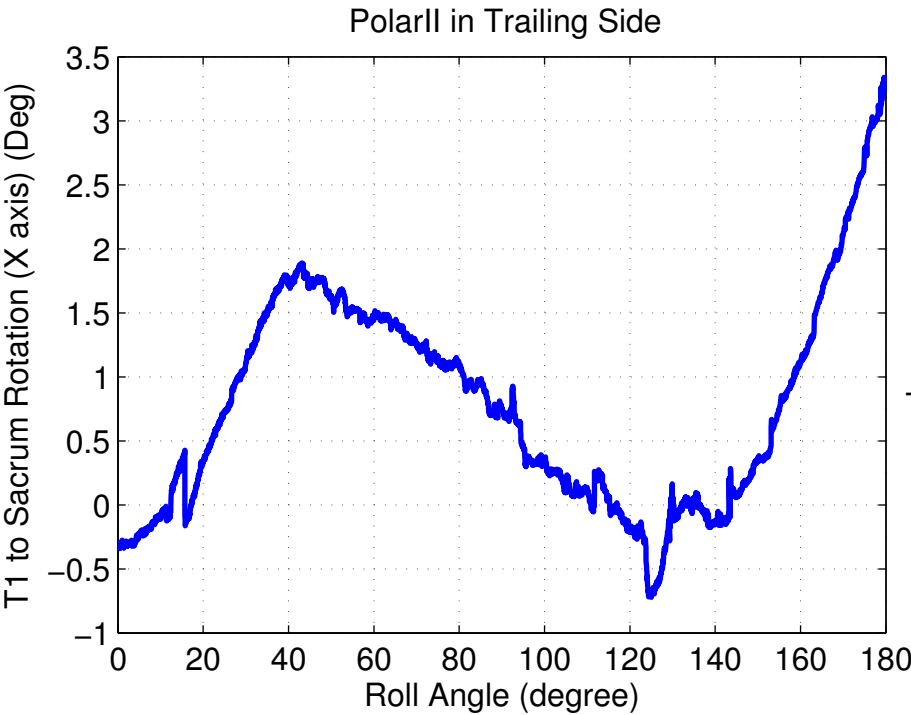


Data Set	Min Roll Ang	Max Roll Ang
	473.13 (115.5)	487.69 (124.2)



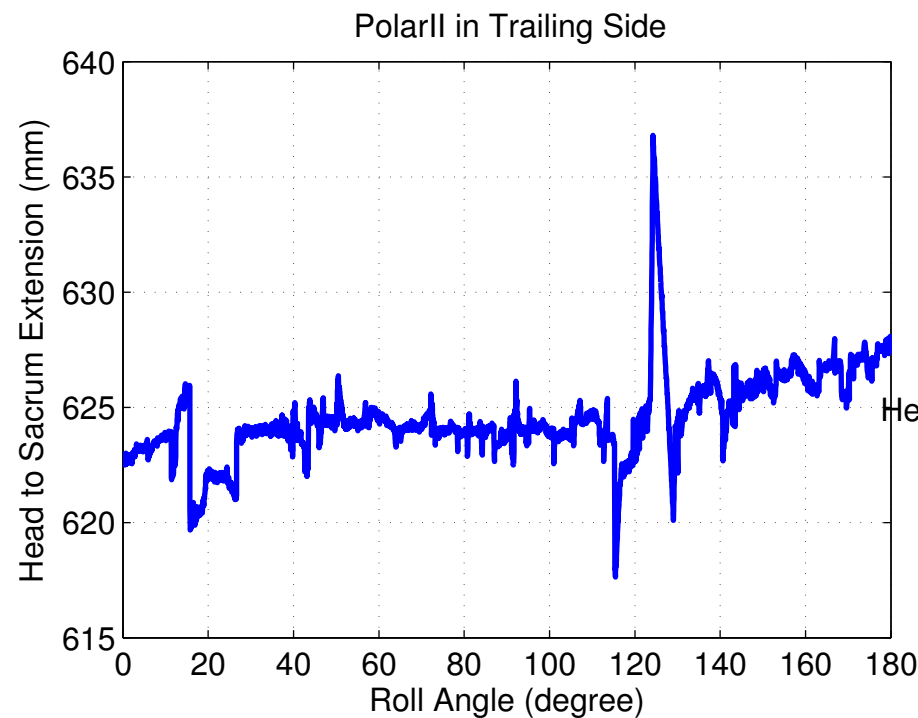


Data Set	Min	Max
	Roll Ang	Roll Ang
	15.10	18.96
T1 to Sacrum Rotation	(183.0)	(15.1)

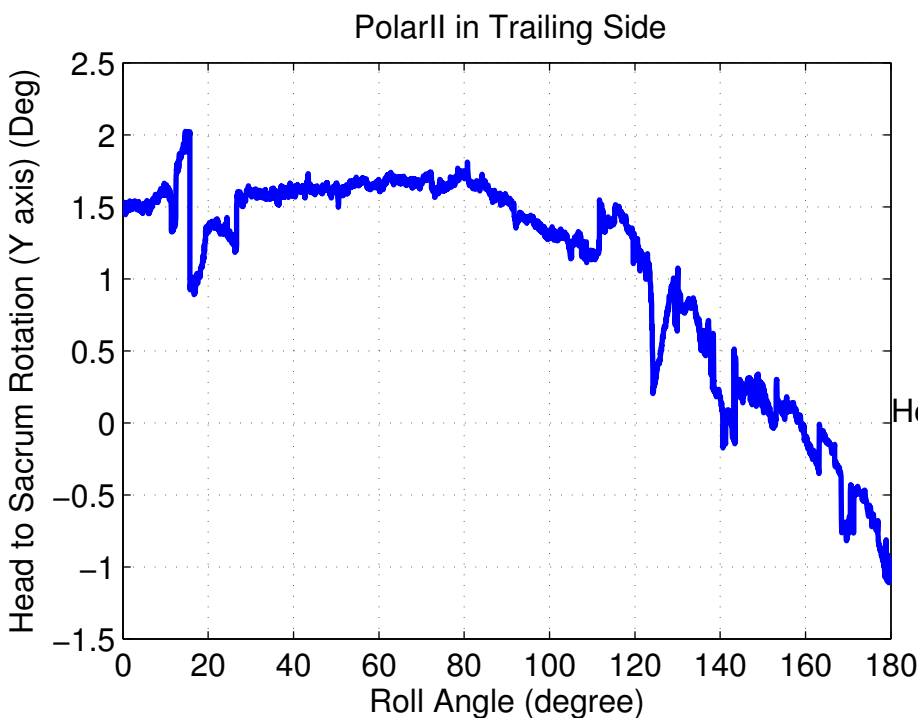


Data Set	Min	Max
	Roll Ang	Roll Ang
	-0.74	3.89
T1 to Sacrum Rotation	(124.8)	(183.0)





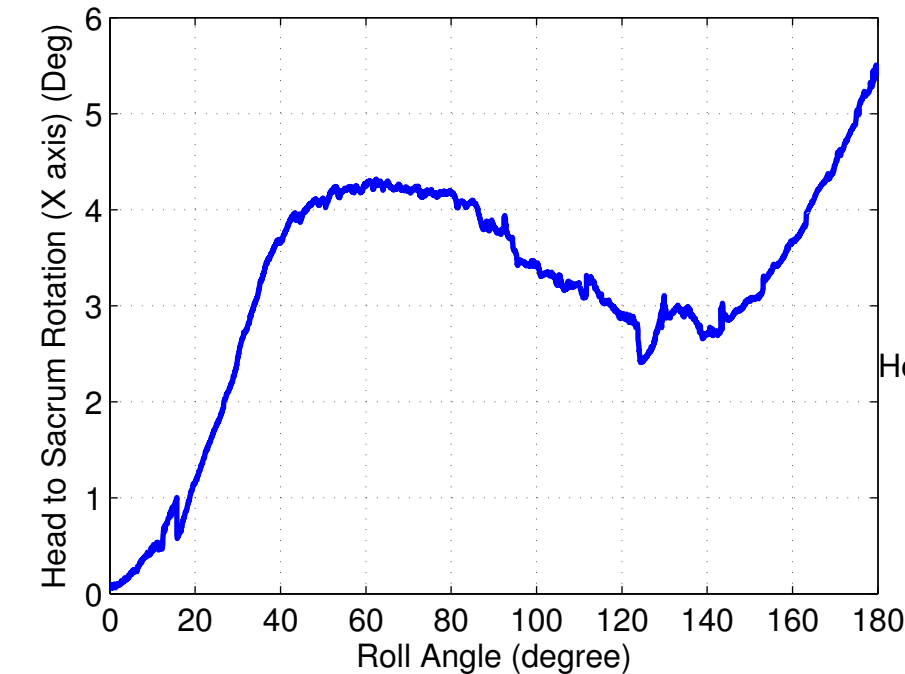
Data Set	Min	Max
	Roll Ang	Roll Ang
	617.63 (15.5)	636.80 (124.2)



Data Set	Min	Max
	Roll Ang	Roll Ang
	-1.53 (183.0)	2.02 (14.6)

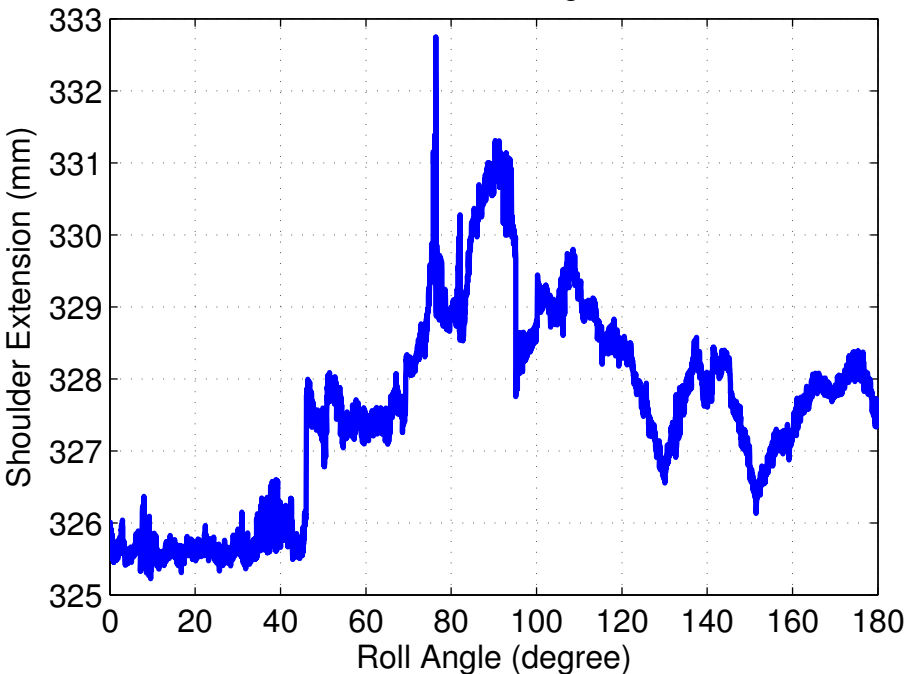


PolarII in Trailing Side



Data Set	Min Roll Ang	Max Roll Ang
Head to Sacrum Rotation	0.06 (0.1)	5.97 (183.0)

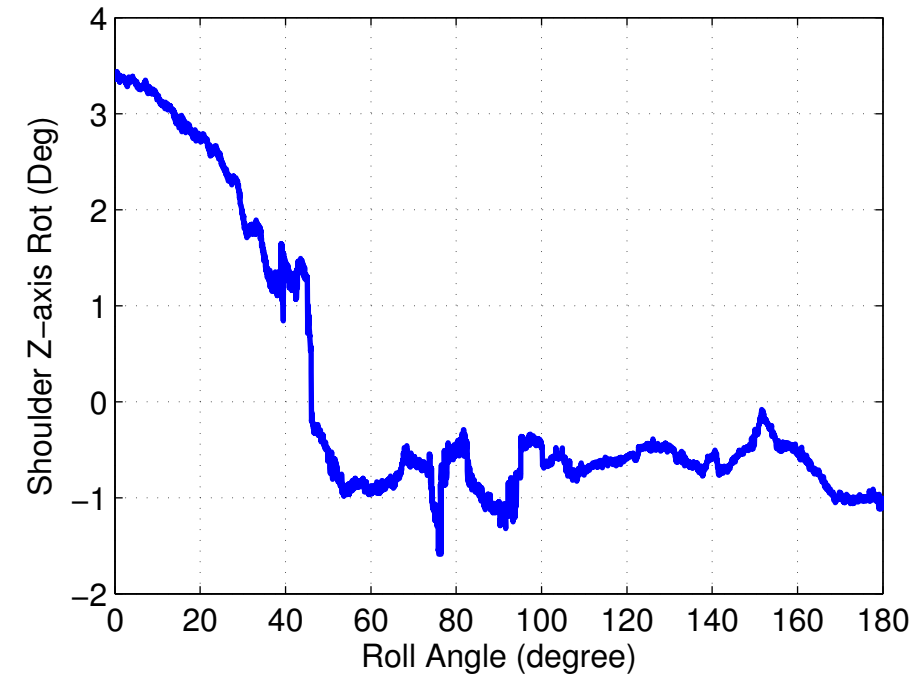
PolarII in Trailing Side



Data Set	Min Roll Ang	Max Roll Ang
Shoulder Extension	325.23 (9.5)	332.74 (76.4)

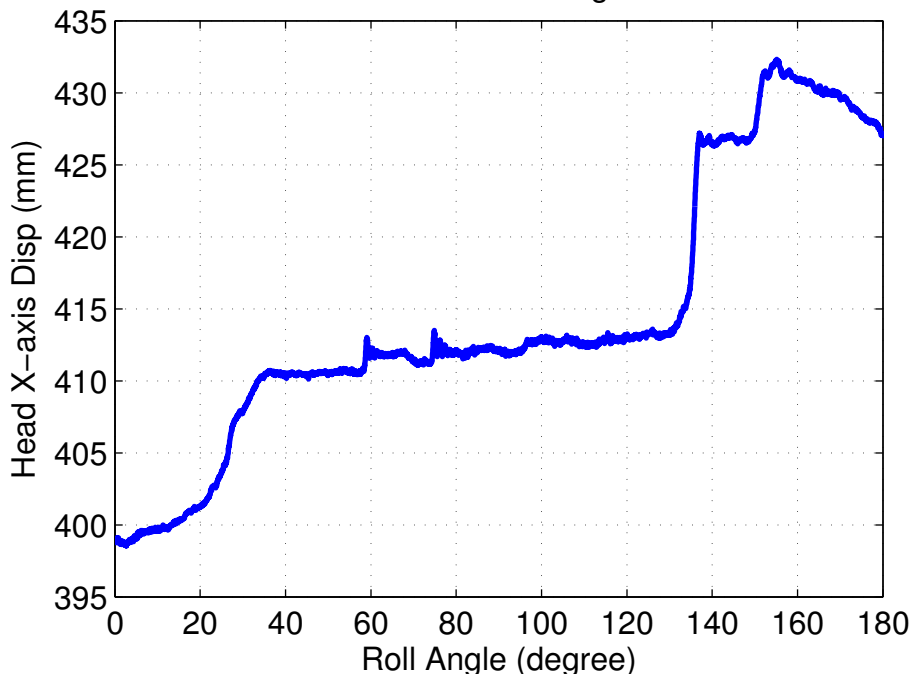


PolarII in Trailing Side



Data Set	Min Roll Ang	Max Roll Ang
Shoulder Z-axis Rot	-1.59 (76.5)	3.44 (0.5)

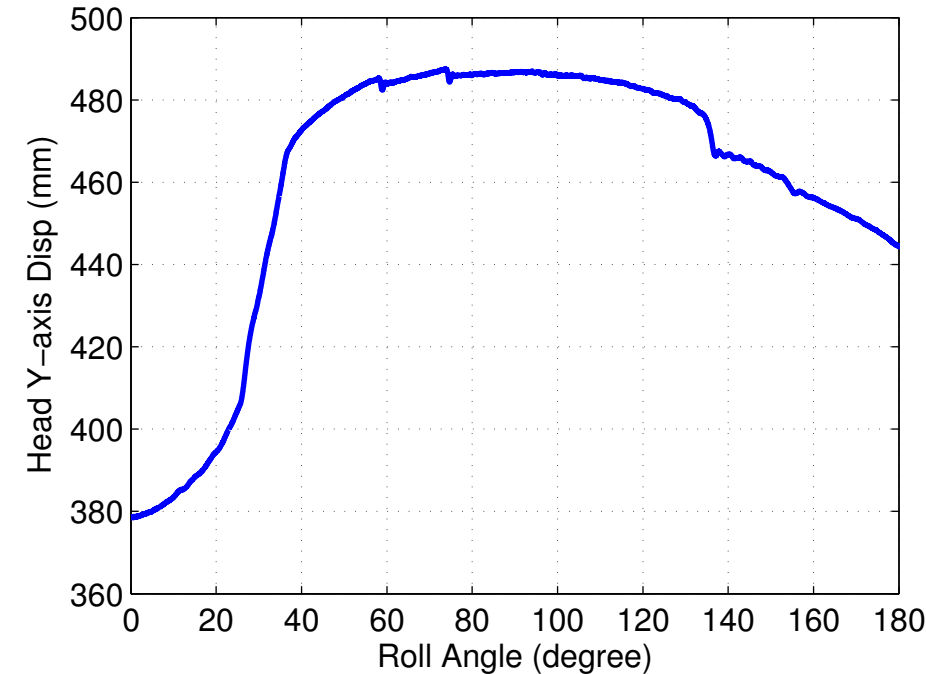
WorldSID in Leading Side



Data Set	Min Roll Ang	Max Roll Ang
Head X-axis Disp	398.54 (2.6)	432.32 (155.2)

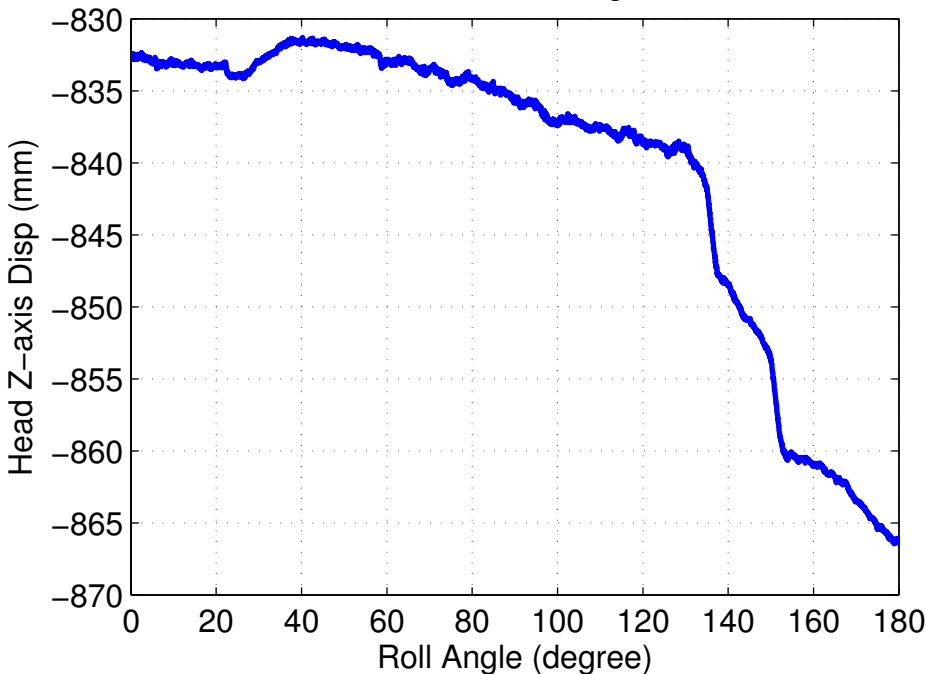


WorldSID in Leading Side



Data Set	Min Roll Ang	Max Roll Ang
Head Y-axis Disp	378.45 (0.5)	487.53 (73.8)

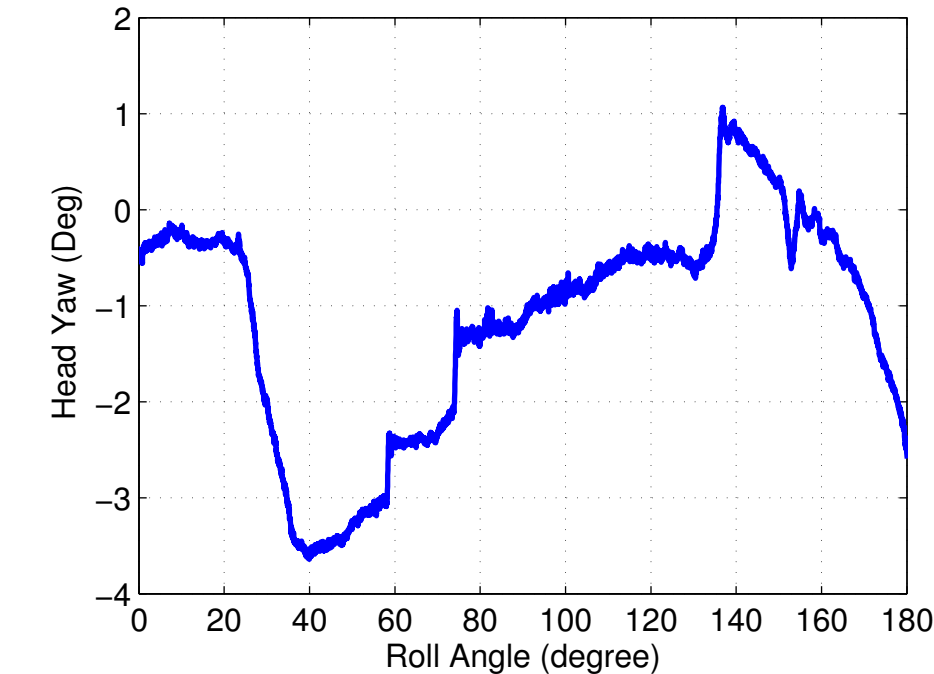
WorldSID in Leading Side



Data Set	Min Roll Ang	Max Roll Ang
Head Z-axis Disp	-867.56 (182.7)	-831.31 (40.2)

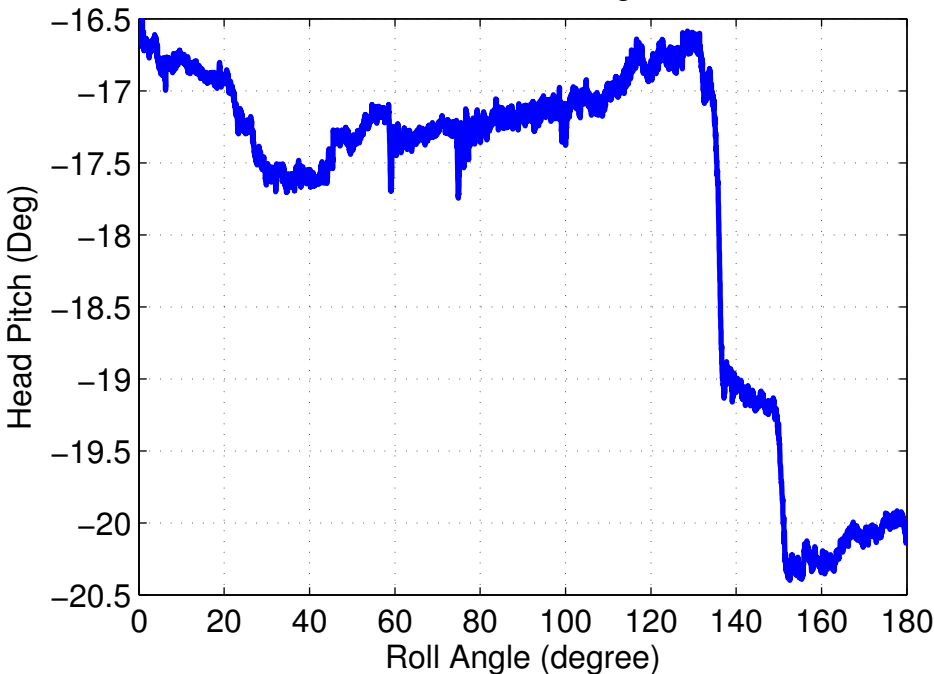


WorldSID in Leading Side



Data Set	Min Roll Ang	Max Roll Ang
Head Yaw	-3.64 (40.0)	1.07 (136.9)

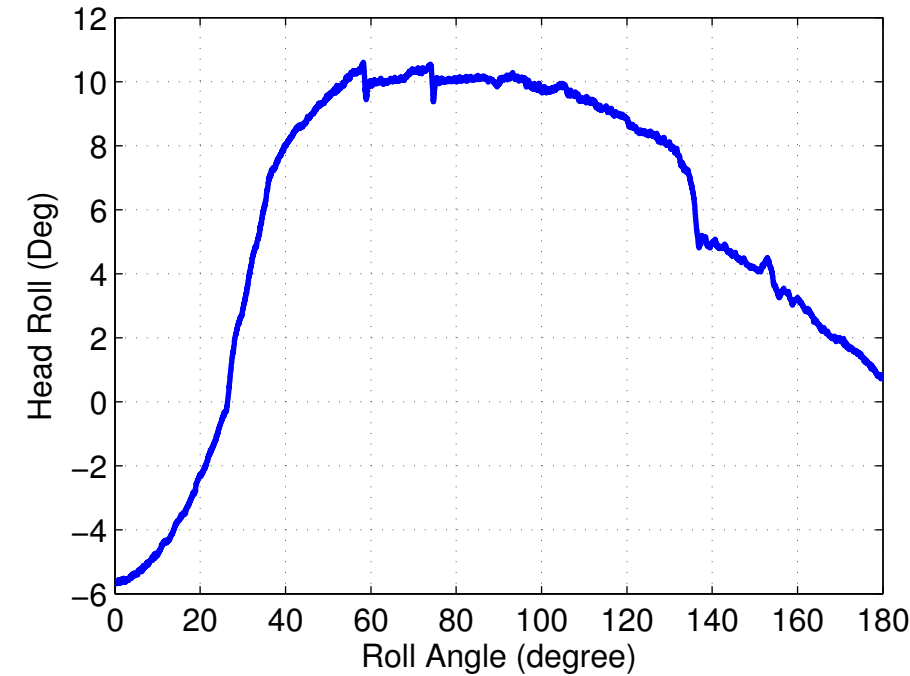
WorldSID in Leading Side



Data Set	Min Roll Ang	Max Roll Ang
Head Pitch	-20.40 (152.6)	-16.51 (0.8)

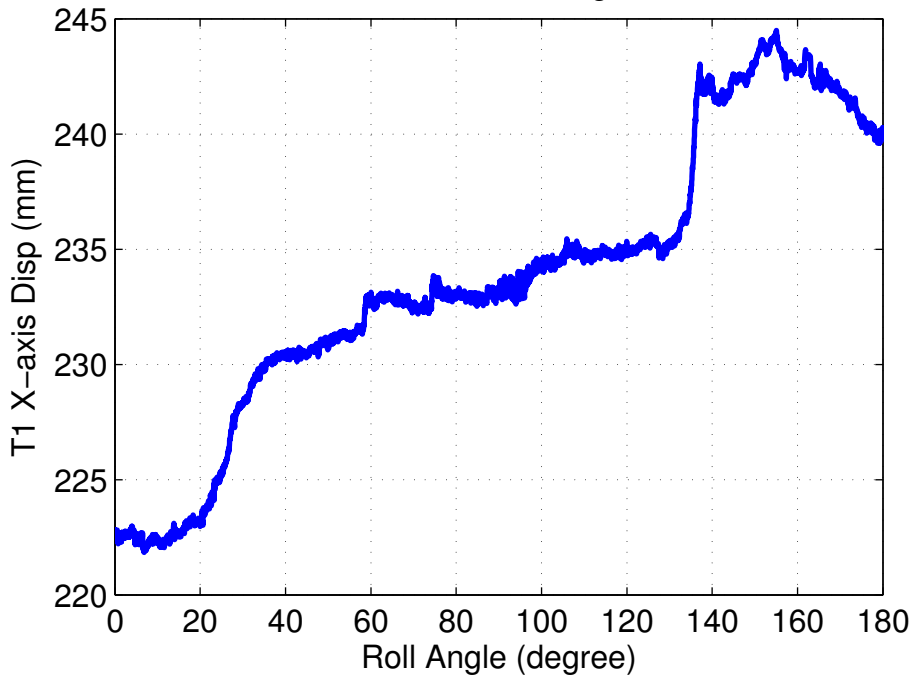


WorldSID in Leading Side



Data Set	Min Roll Ang	Max Roll Ang
Head Roll	-5.69 (0.0)	10.61 (58.2)

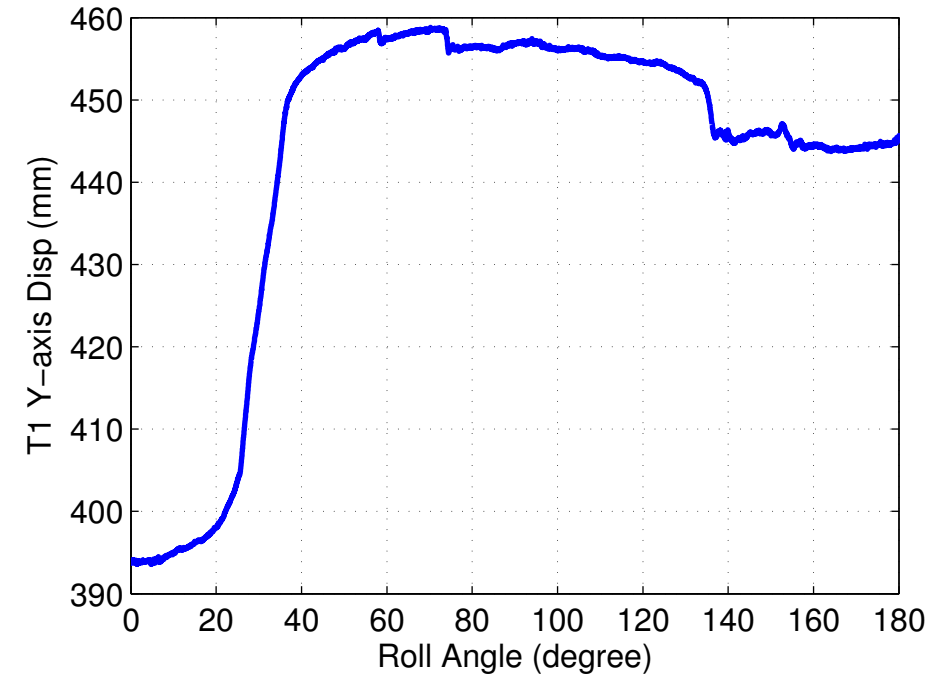
WorldSID in Leading Side



Data Set	Min Roll Ang	Max Roll Ang
T1 X-axis Disp	221.84 (6.8)	244.49 (155.1)

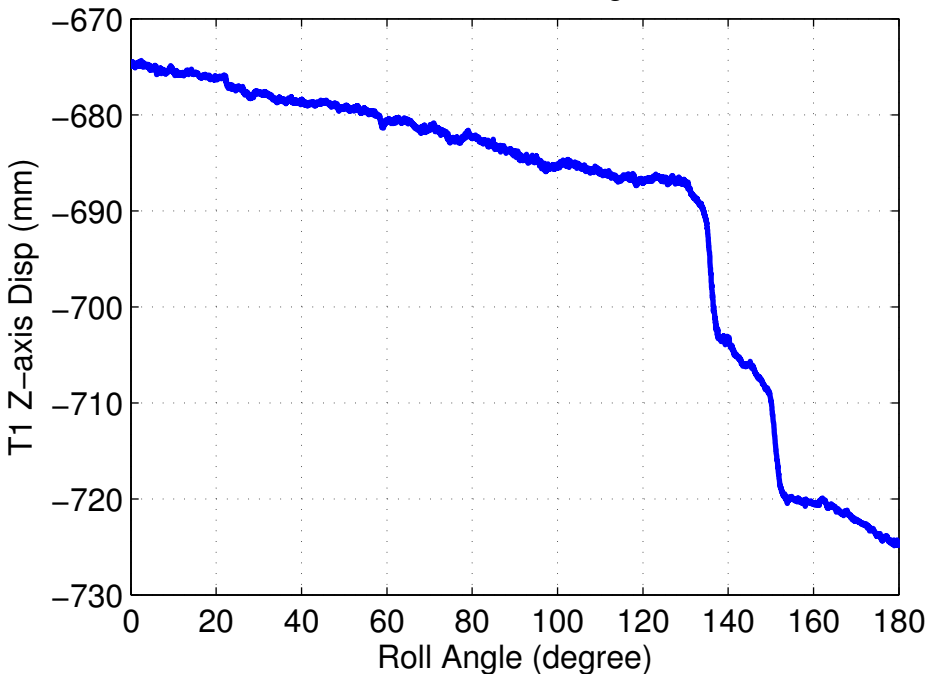


WorldSID in Leading Side



Data Set	Min	Max
	Roll Ang	Roll Ang
T1 Y-axis Disp	393.57 (1.4)	458.80 (70.2)

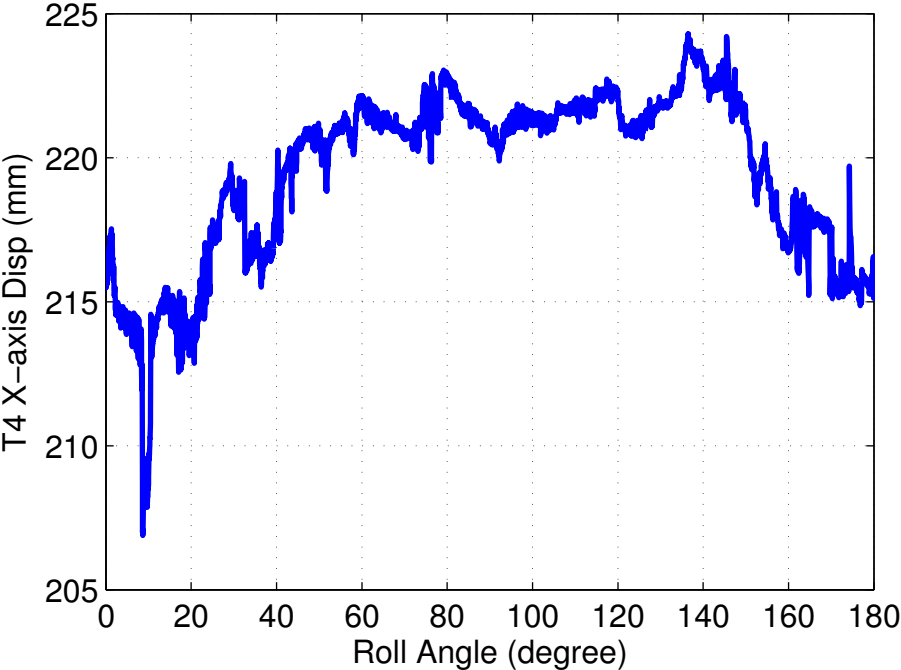
WorldSID in Leading Side



Data Set	Min	Max
	Roll Ang	Roll Ang
T1 Z-axis Disp	-725.90 (182.7)	-674.36 (2.5)

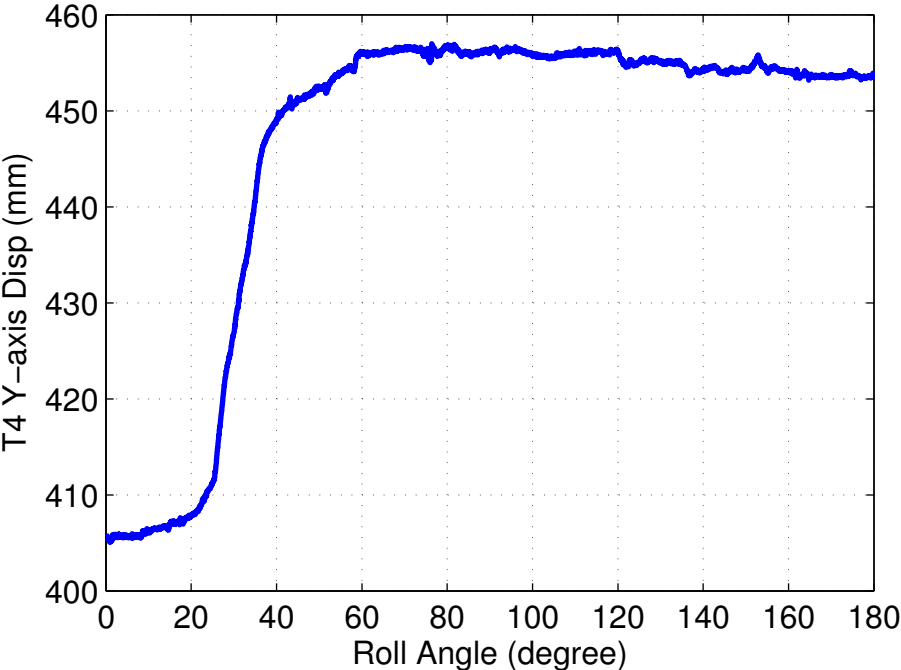


WorldSID in Leading Side



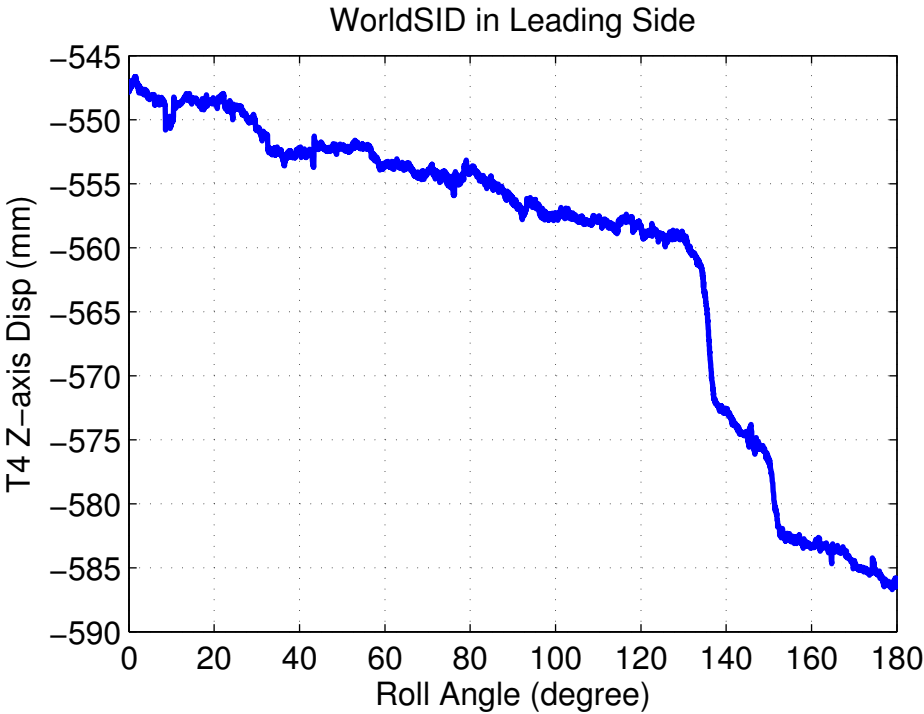
Data Set	Min Roll Ang	Max Roll Ang
T4 X-axis Disp	206.88 (8.7)	224.30 (136.5)

WorldSID in Leading Side

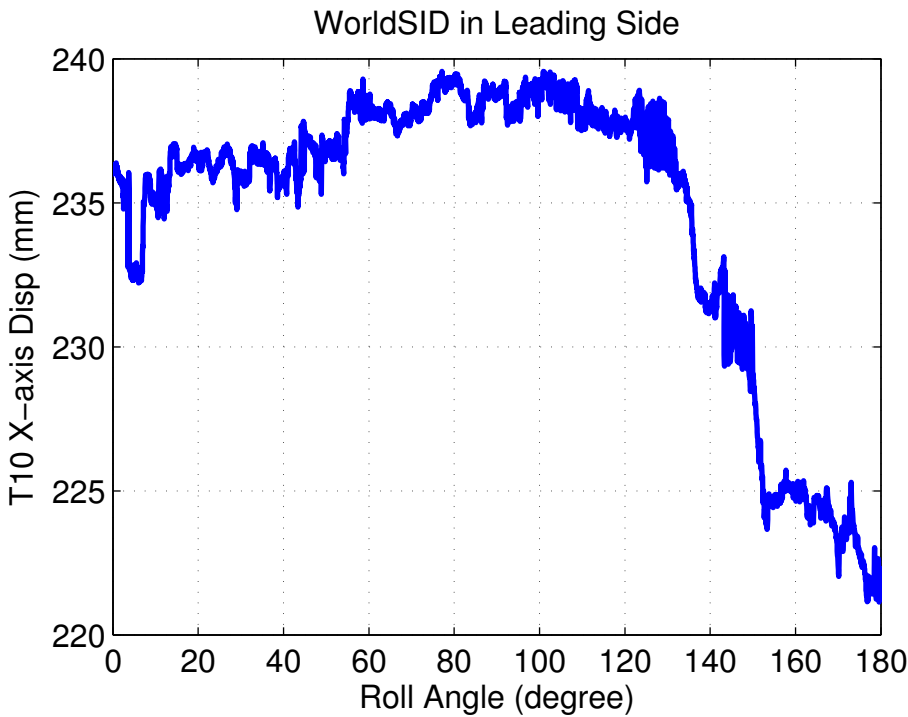


Data Set	Min Roll Ang	Max Roll Ang
T4 Y-axis Disp	405.08 (1.0)	456.98 (76.4)





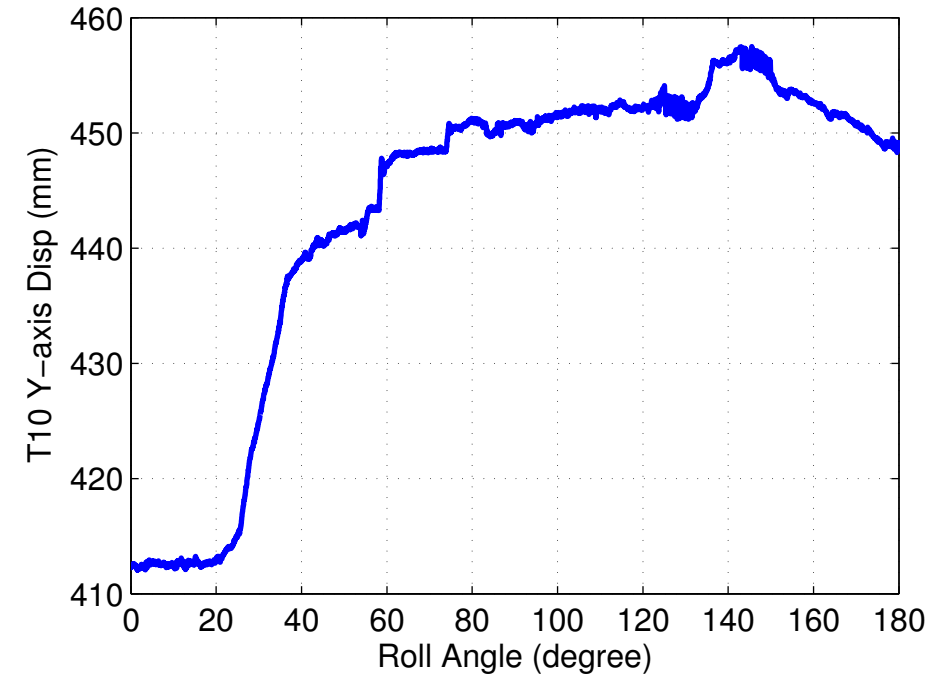
Data Set	Min Roll Ang	Max Roll Ang
T4 Z-axis Disp	-587.48 (182.7)	-546.63 (1.6)



Data Set	Min Roll Ang	Max Roll Ang
T10 X-axis Disp	217.97 (181.7)	239.56 (100.9)

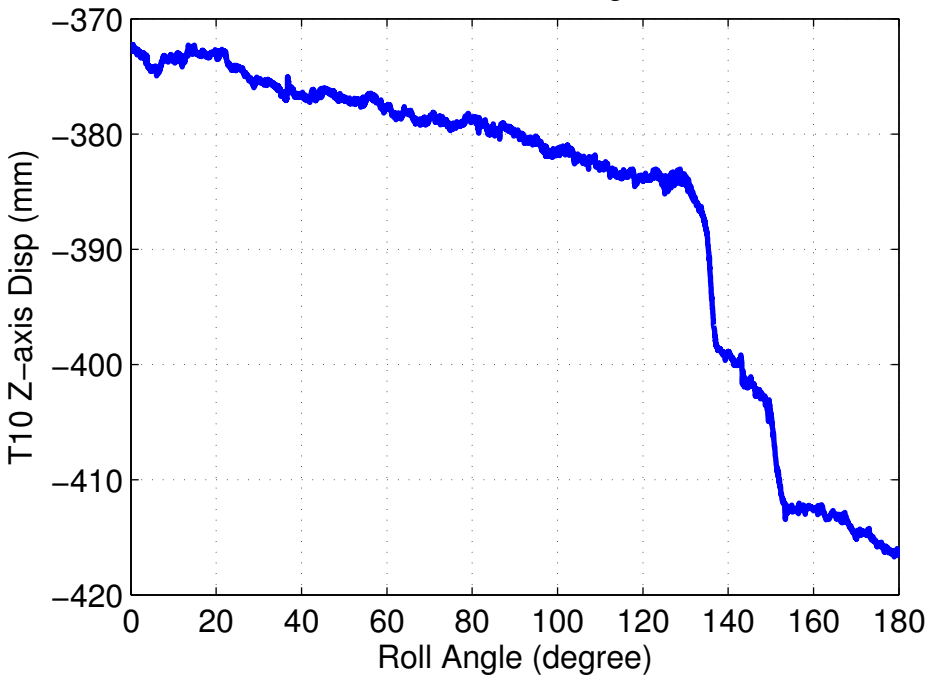


WorldSID in Leading Side



Data Set	Min Roll Ang	Max Roll Ang
T10 Y-axis Disp	412.05 (1.5)	457.50 (145.6)

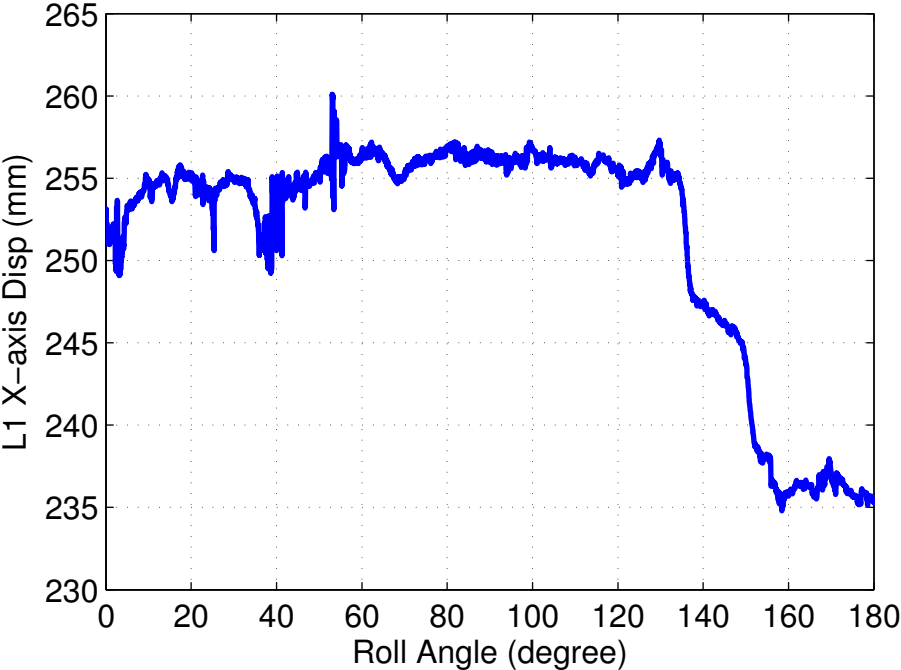
WorldSID in Leading Side



Data Set	Min Roll Ang	Max Roll Ang
T10 Z-axis Disp	-417.92 (181.6)	-372.24 (0.5)

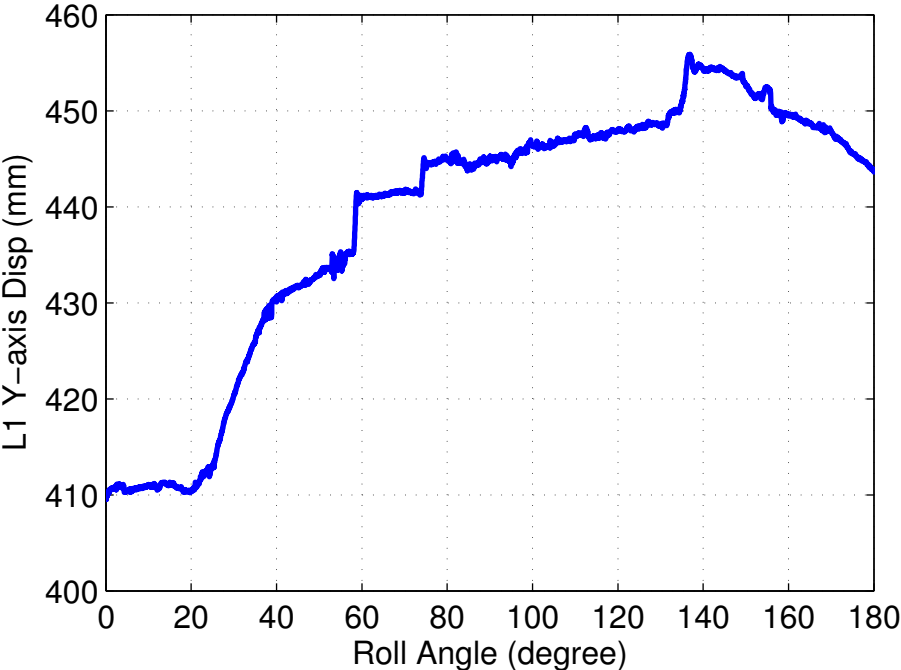


WorldSID in Leading Side



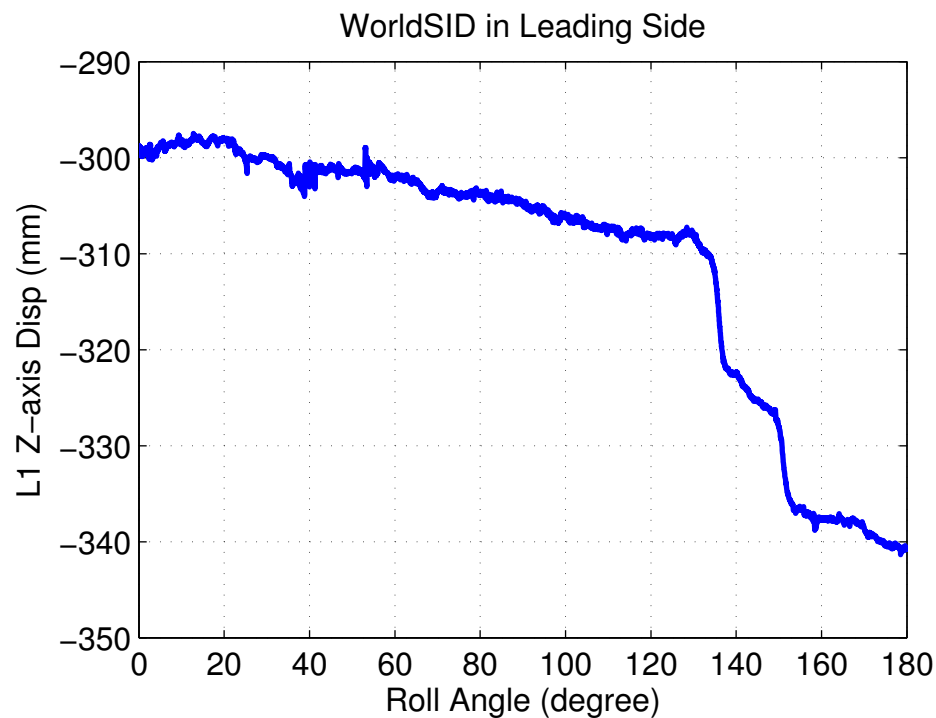
Data Set	Min	Max
	Roll Ang	Roll Ang
L1 X-axis Disp	234.58 (182.7)	260.09 (53.1)

WorldSID in Leading Side

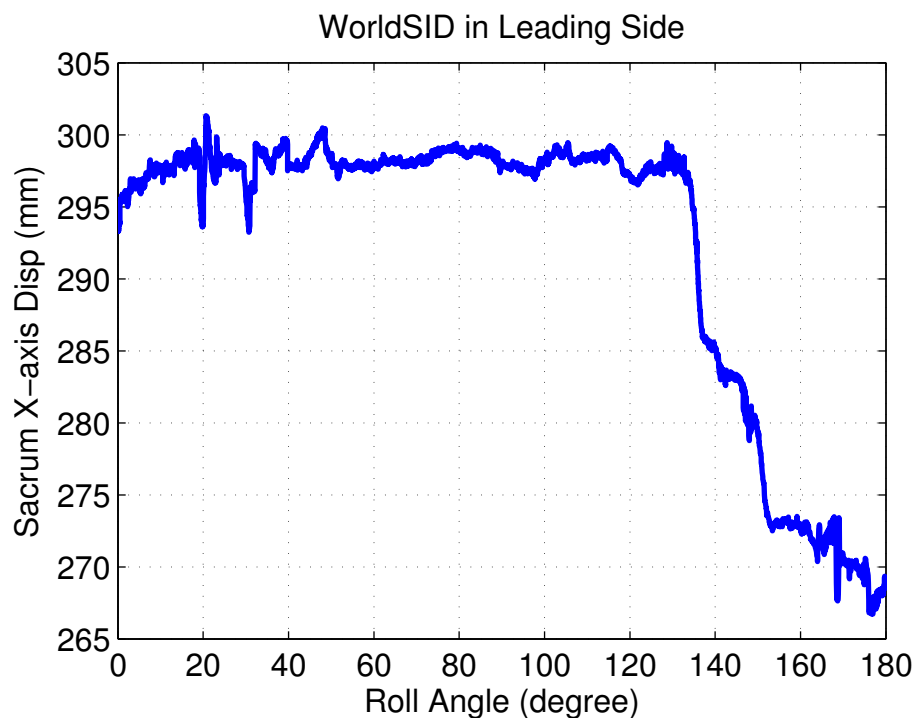


Data Set	Min	Max
	Roll Ang	Roll Ang
L1 Y-axis Disp	409.52 (0.1)	455.89 (136.9)





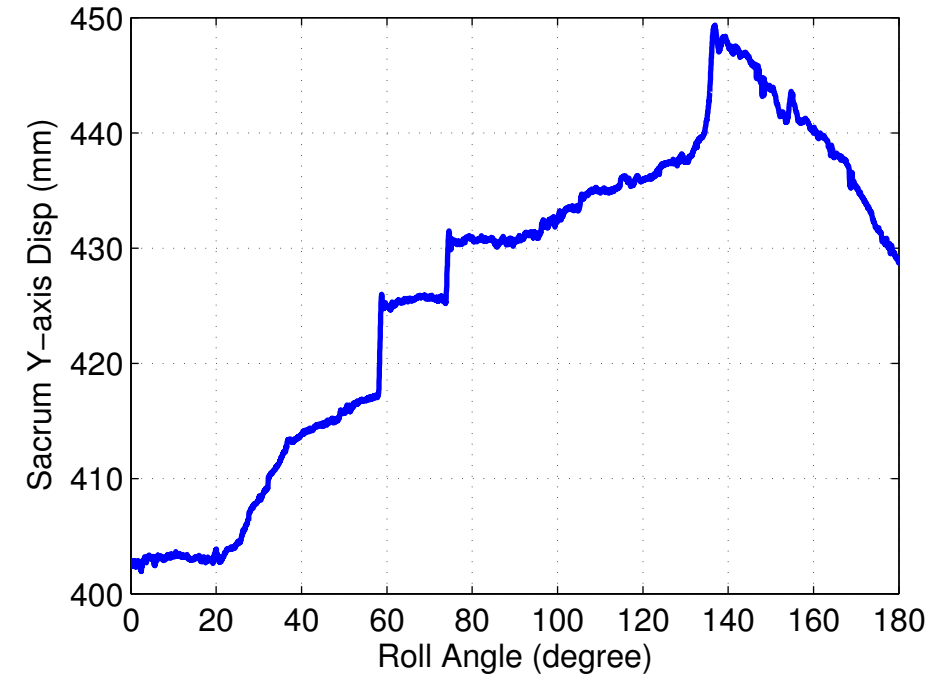
Data Set	Min Roll Ang	Max Roll Ang
L1 Z-axis Disp	-341.72 (183.0)	-297.49 (12.8)



Data Set	Min Roll Ang	Max Roll Ang
Sacrum X-axis Disp	265.61 (183.0)	301.32 (20.7)

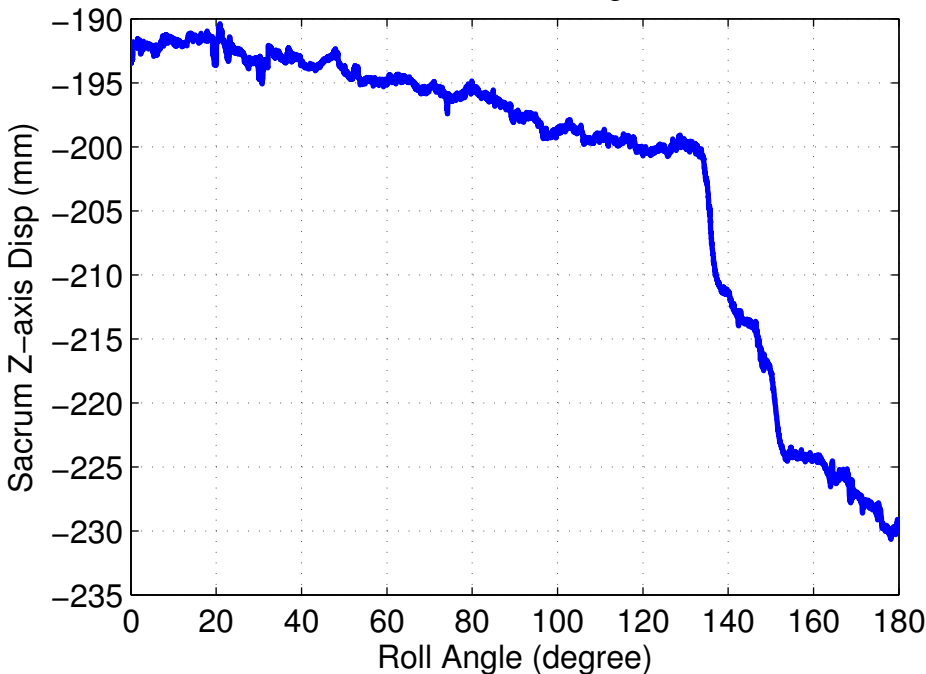


WorldSID in Leading Side



Data Set	Min Roll Ang	Max Roll Ang
Sacrum Y-axis Disp	401.94 (2.4)	449.34 (136.9)

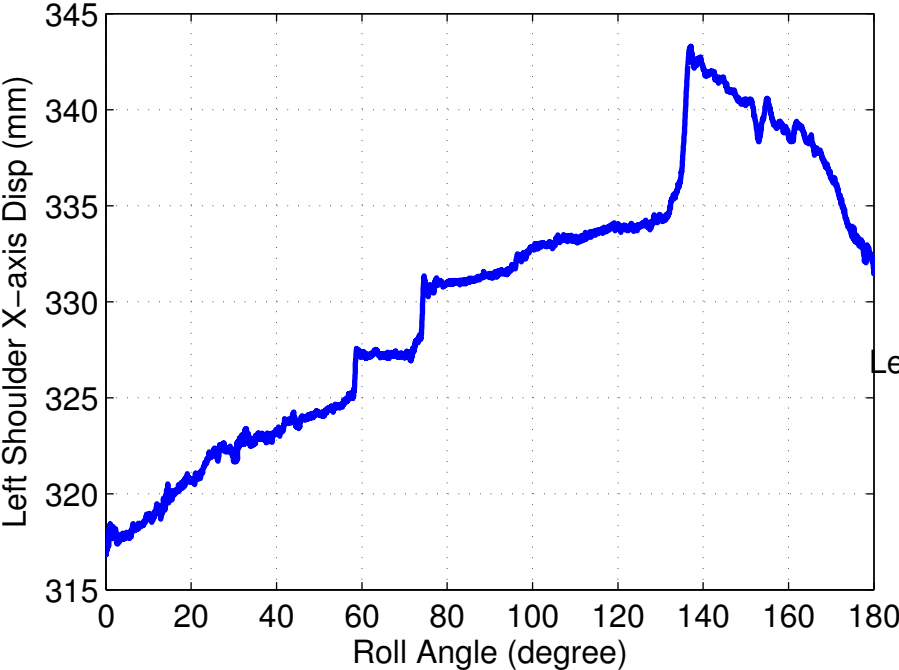
WorldSID in Leading Side



Data Set	Min Roll Ang	Max Roll Ang
Sacrum Z-axis Disp	-230.92 (182.5)	-190.38 (20.9)

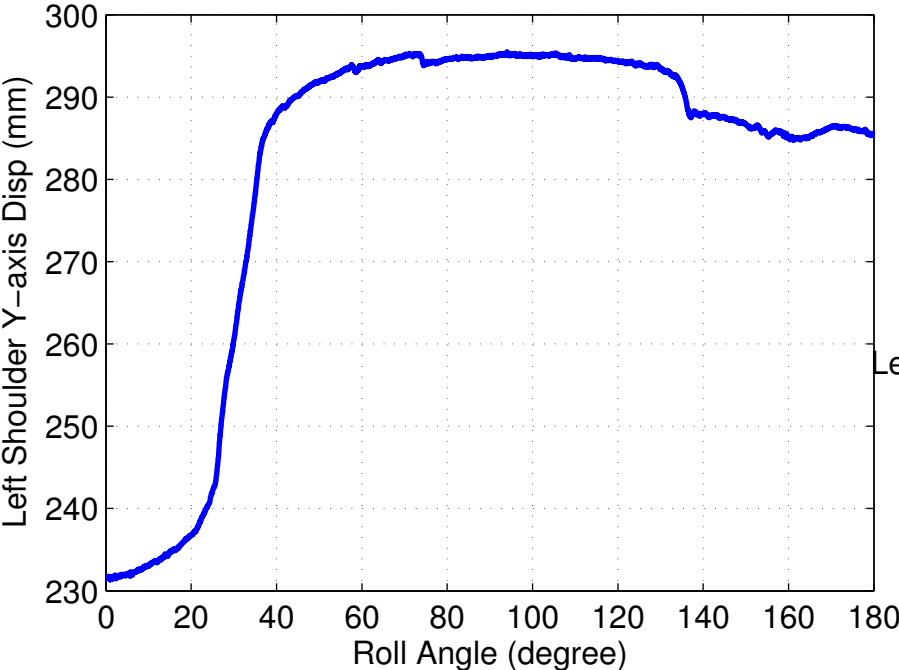


WorldSID in Leading Side



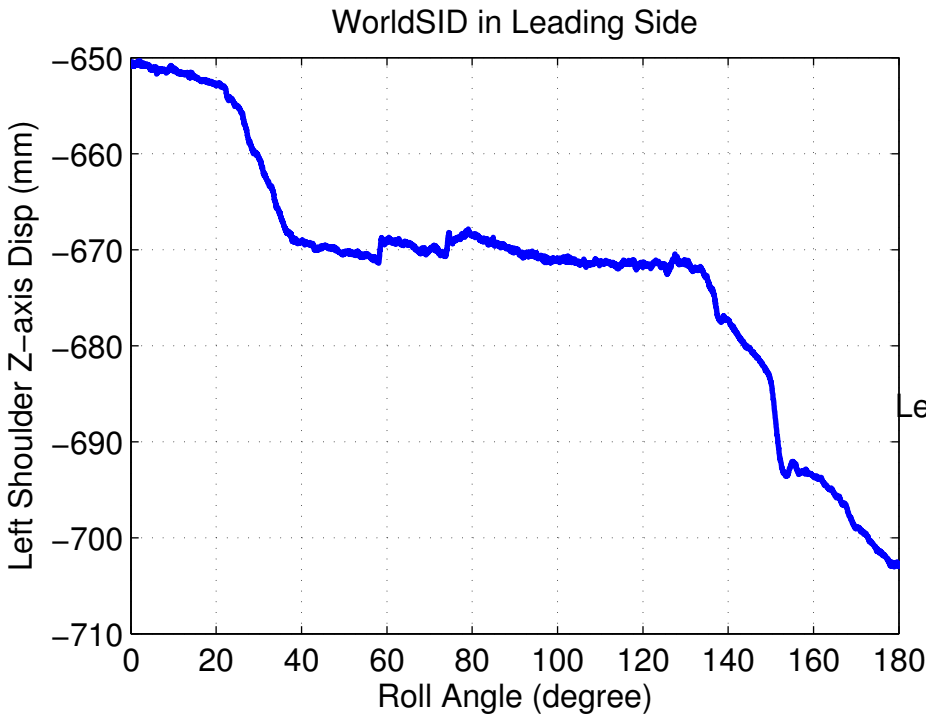
Data Set	Min Roll Ang	Max Roll Ang
	316.84 (0.1)	343.30 (137.1)

WorldSID in Leading Side

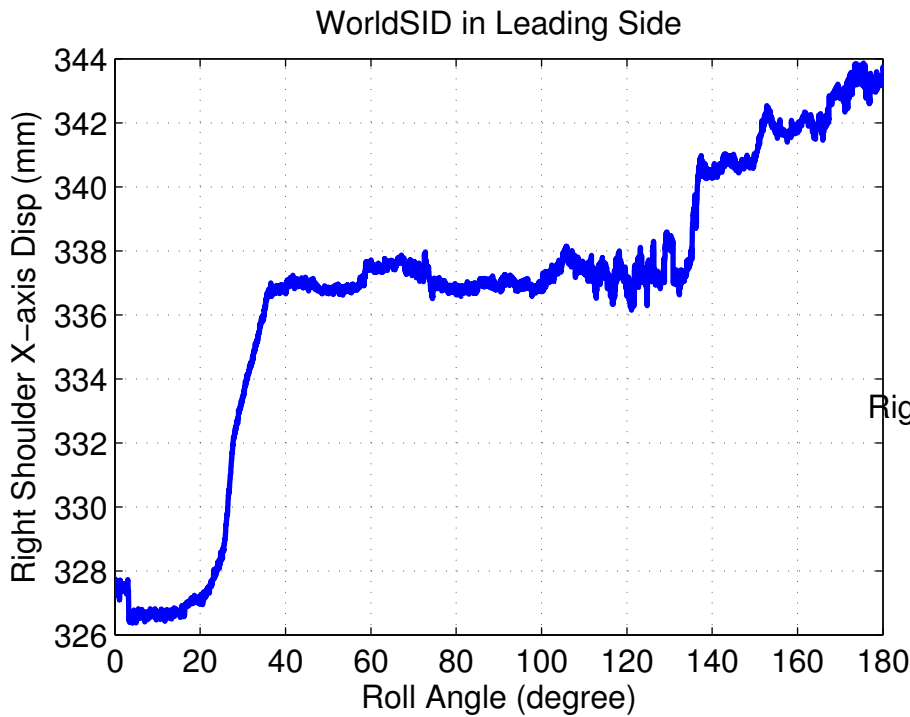


Data Set	Min Roll Ang	Max Roll Ang
	231.34 (0.0)	295.50 (94.0)



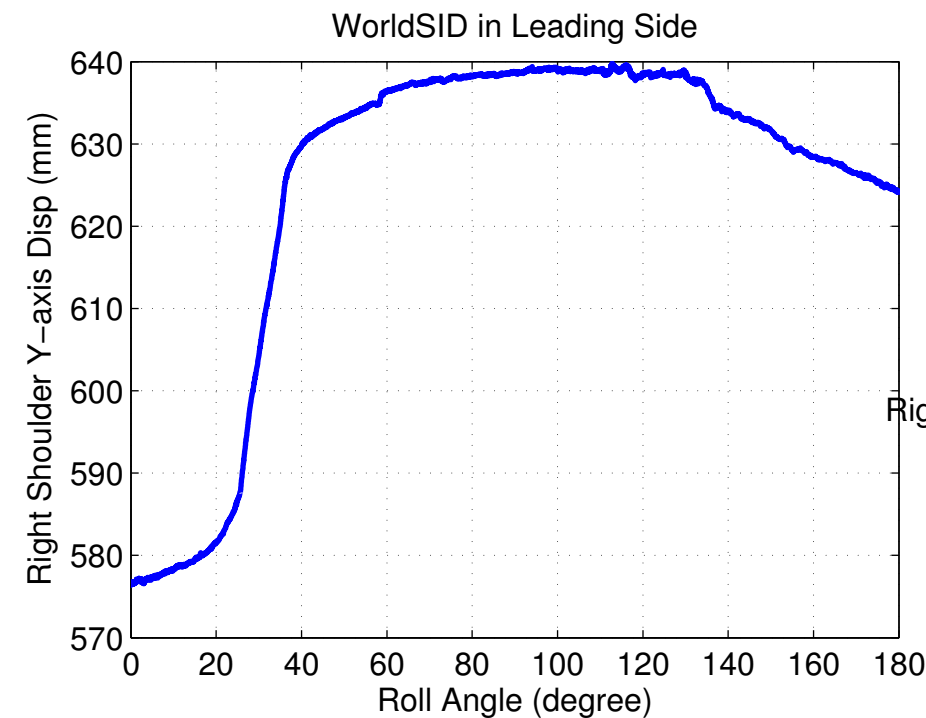


Data Set	Min Roll Ang	Max Roll Ang
Left Shoulder Z-axis Disp	-705.70 (182.2)	-650.33 (2.2)

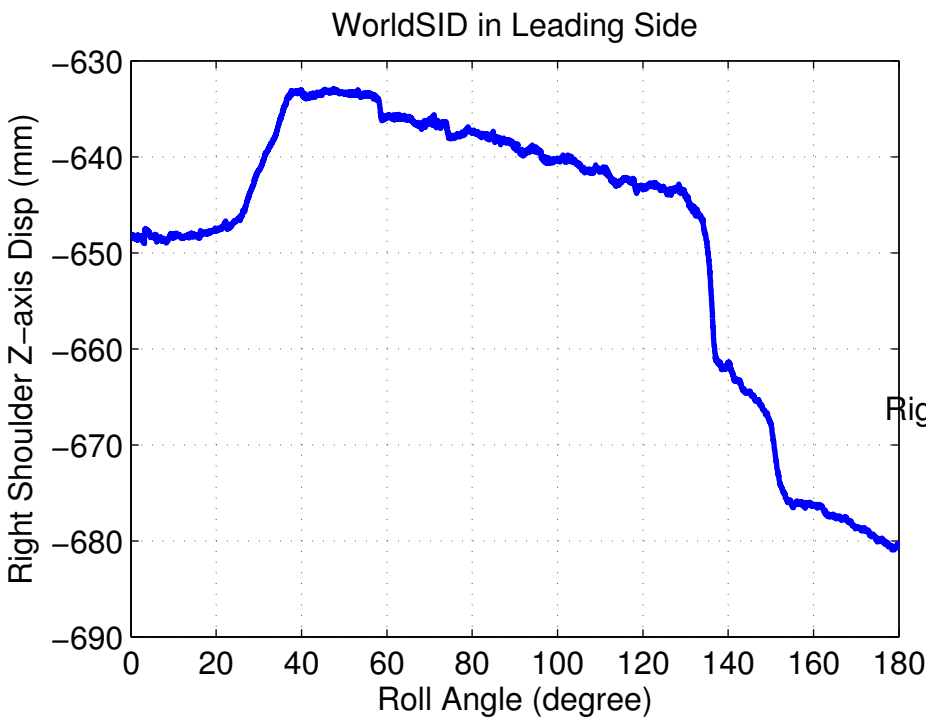


Data Set	Min Roll Ang	Max Roll Ang
Right Shoulder X-axis Disp	326.37 (4.1)	344.69 (181.5)



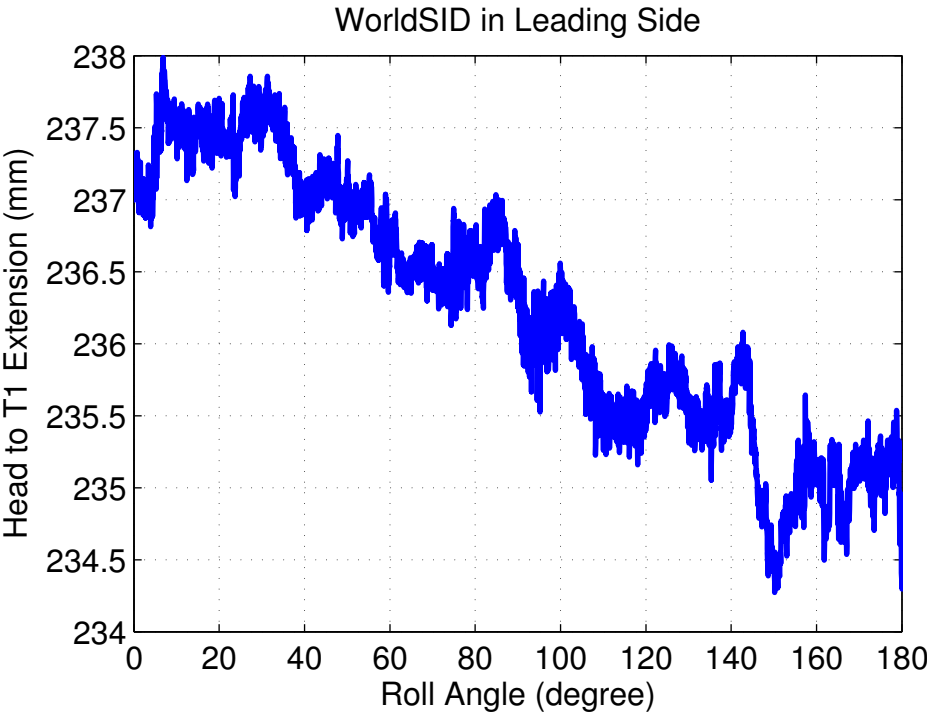


Data Set	Min Roll Ang	Max Roll Ang
Right Shoulder Y-axis Disp	576.41 (0.1)	639.81 (112.8)

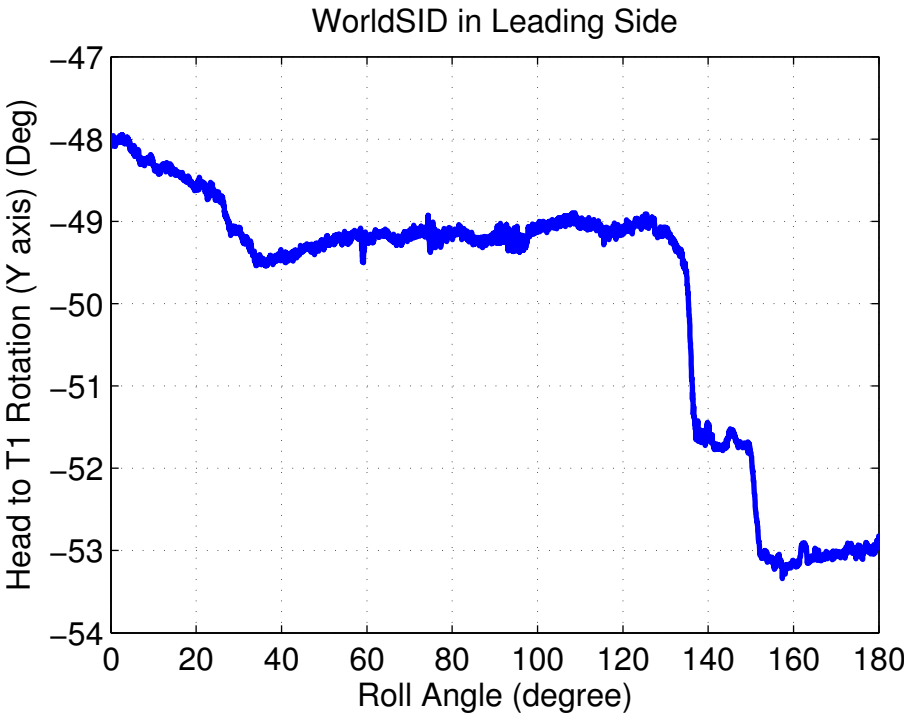


Data Set	Min Roll Ang	Max Roll Ang
Right Shoulder Z-axis Disp	-681.10 (183.0)	-632.90 (47.5)





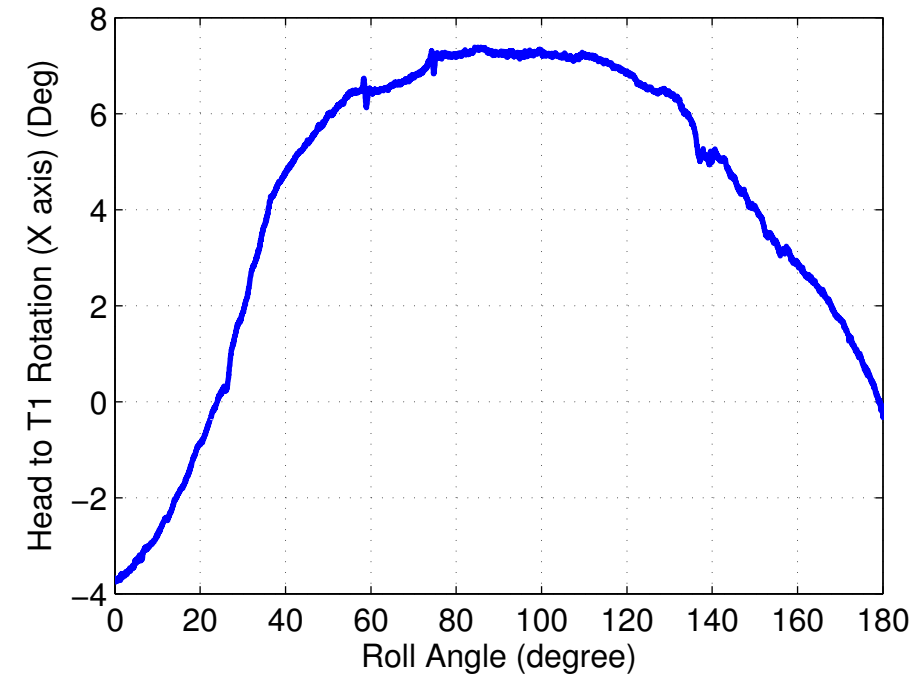
Data Set	Min Roll Ang	Max Roll Ang
Head to T1 Extension	234.27 (150.2)	237.99 (6.9)



Data Set	Min Roll Ang	Max Roll Ang
Head to T1 Rotation	-53.34 (157.4)	-47.95 (2.6)

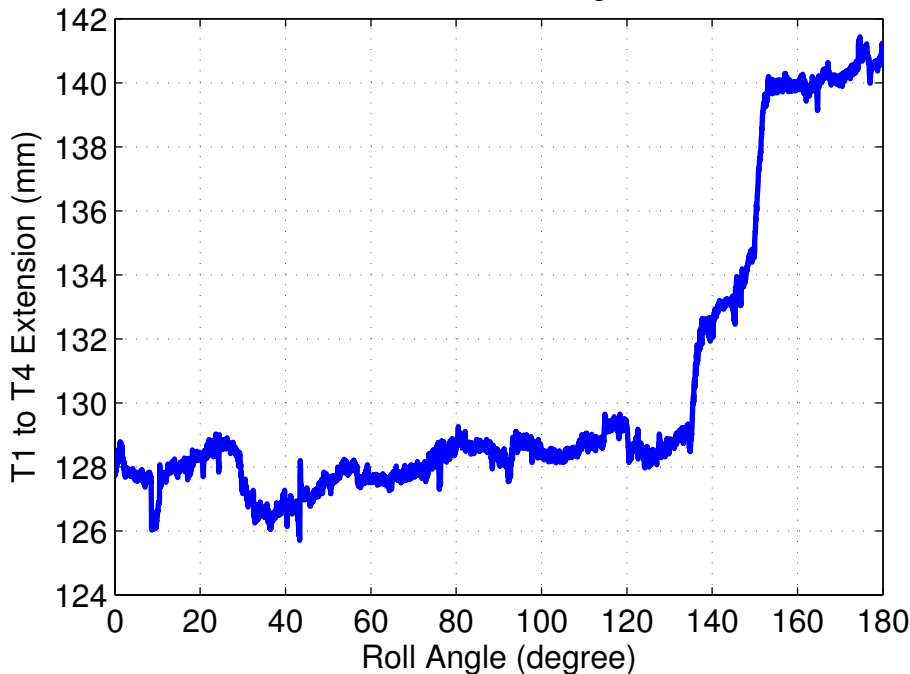


WorldSID in Leading Side



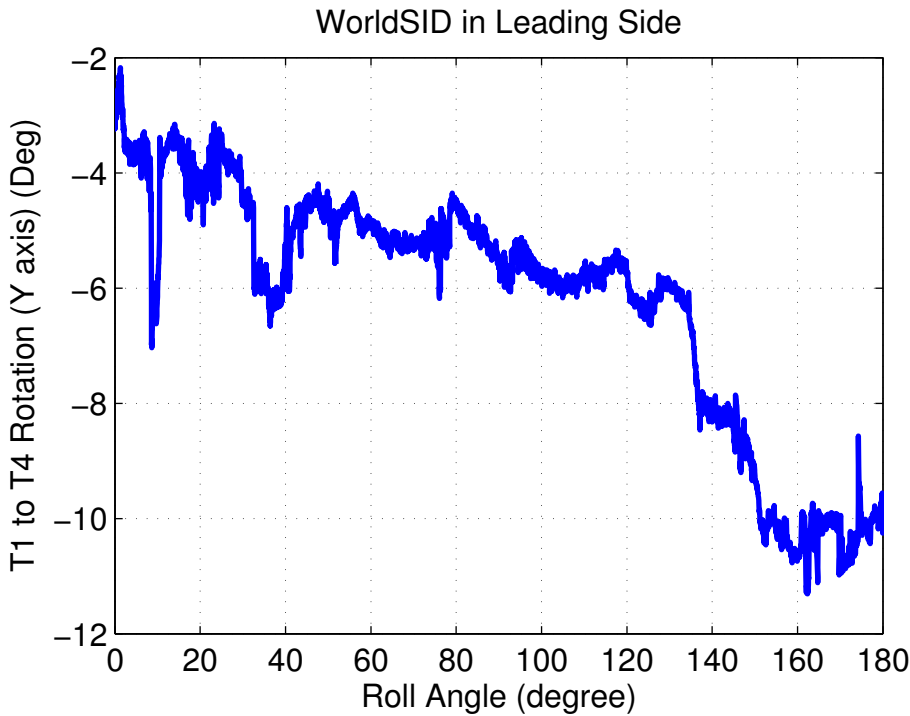
Data Set	Min Roll Ang	Max Roll Ang
Head to T1 Rotation	-3.75 (0.3)	7.38 (85.7)

WorldSID in Leading Side

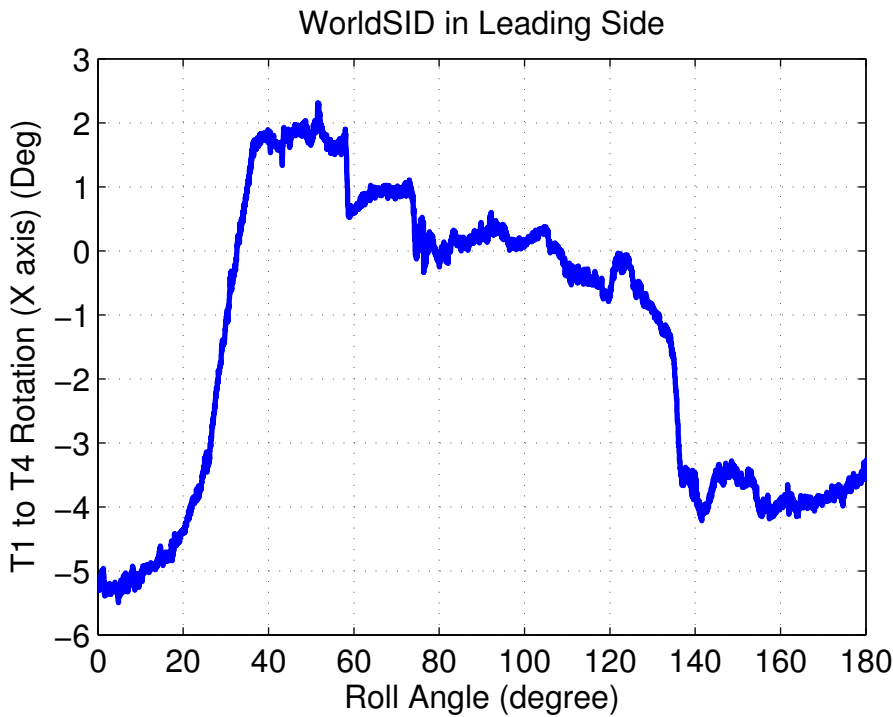


Data Set	Min Roll Ang	Max Roll Ang
T1 to T4 Extension	125.71 (43.3)	141.49 (180.4)





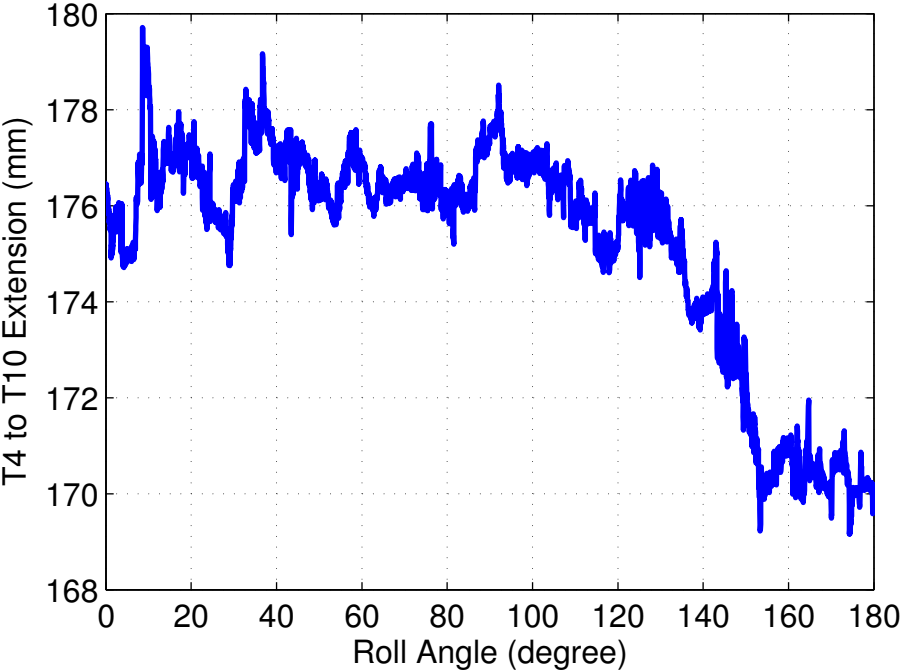
Data Set	Min Roll Ang	Max Roll Ang
T1 to T4 Rotation	-11.31 (162.3)	-2.17 (1.3)



Data Set	Min Roll Ang	Max Roll Ang
T1 to T4 Rotation	-5.50 (4.8)	2.31 (51.5)

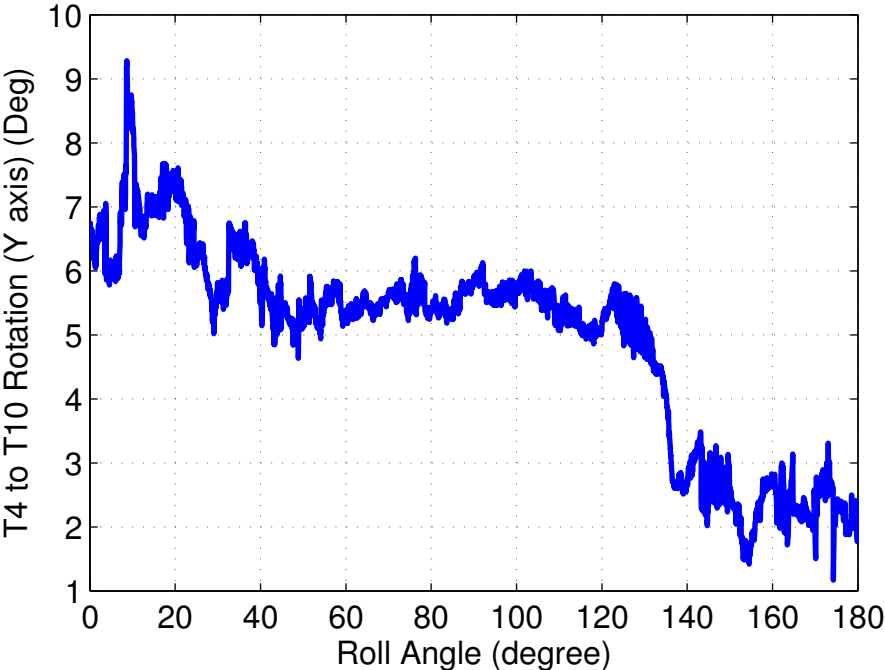


WorldSID in Leading Side



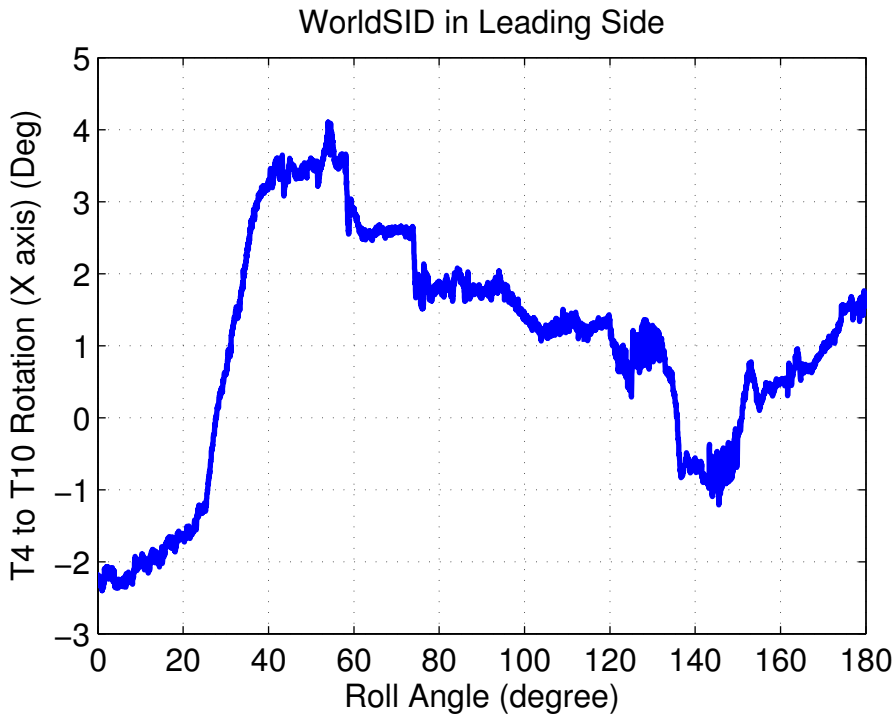
Data Set	Min	Max
	Roll Ang	Roll Ang
T4 to T10 Extension	168.94 (181.7)	179.71 (8.6)

WorldSID in Leading Side

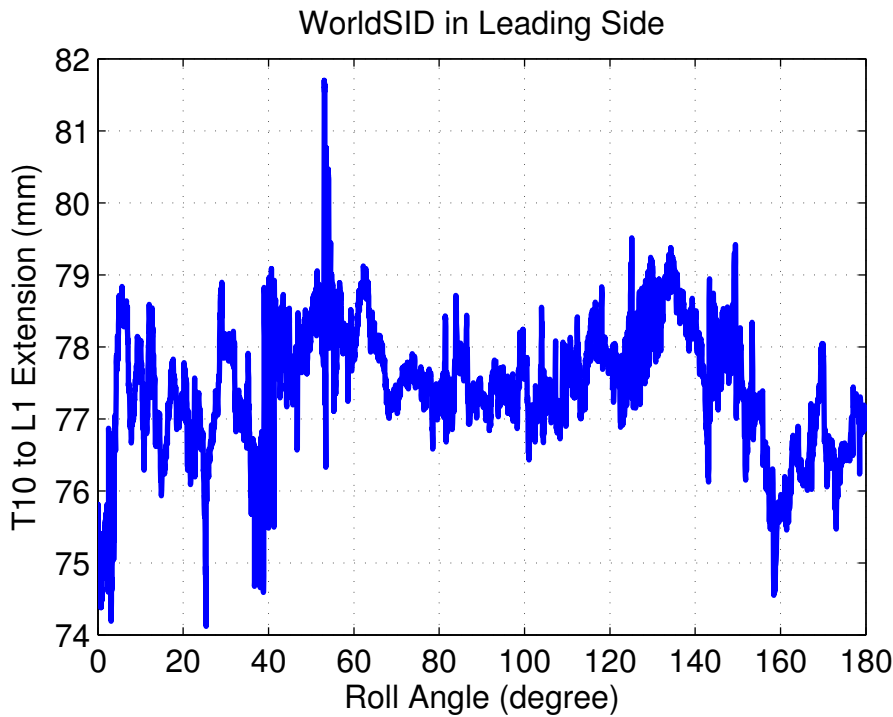


Data Set	Min	Max
	Roll Ang	Roll Ang
T4 to T10 Rotation	1.16 (181.7)	9.28 (8.7)



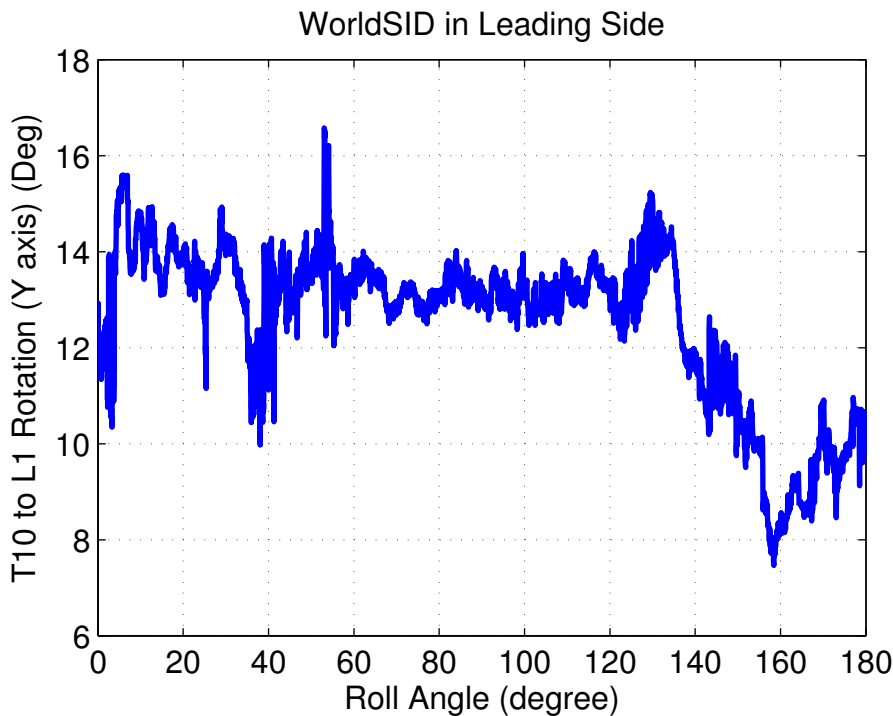


Data Set	Min Roll Ang	Max Roll Ang
T4 to T10 Rotation	-2.40 (1.0)	4.11 (54.0)

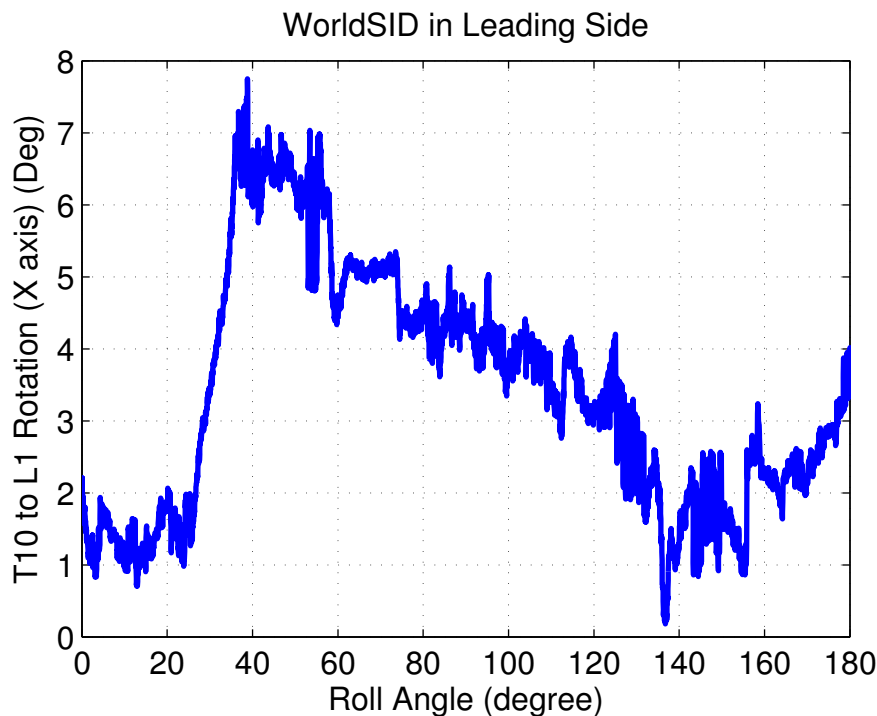


Data Set	Min Roll Ang	Max Roll Ang
T10 to L1 Extension	74.12 (25.4)	81.70 (53.1)





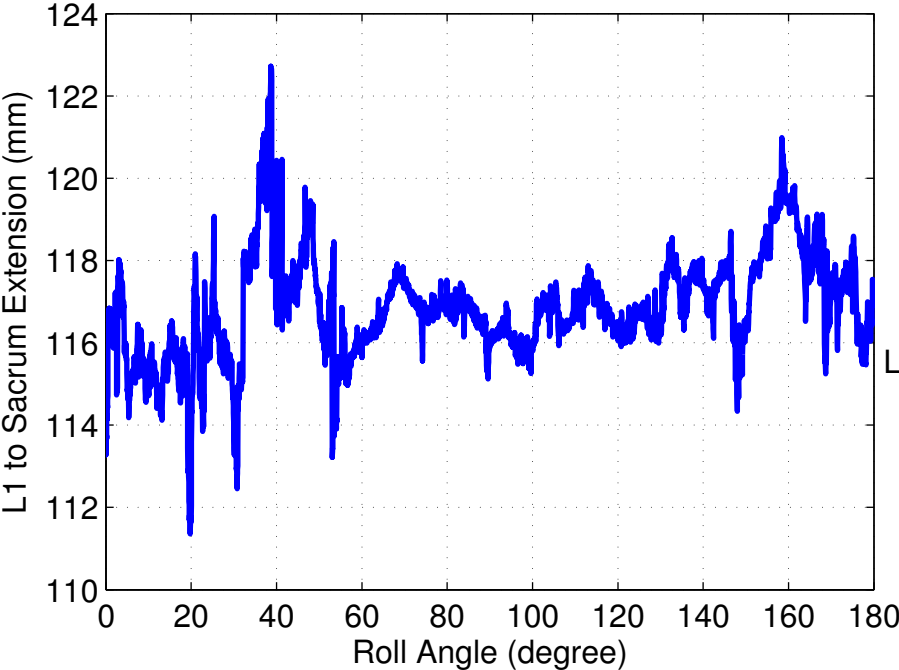
Data Set	Min Roll Ang	Max Roll Ang
T10 to L1 Rotation	7.46 (158.4)	16.58 (53.1)



Data Set	Min Roll Ang	Max Roll Ang
T10 to L1 Rotation	0.18 (136.8)	7.75 (38.8)

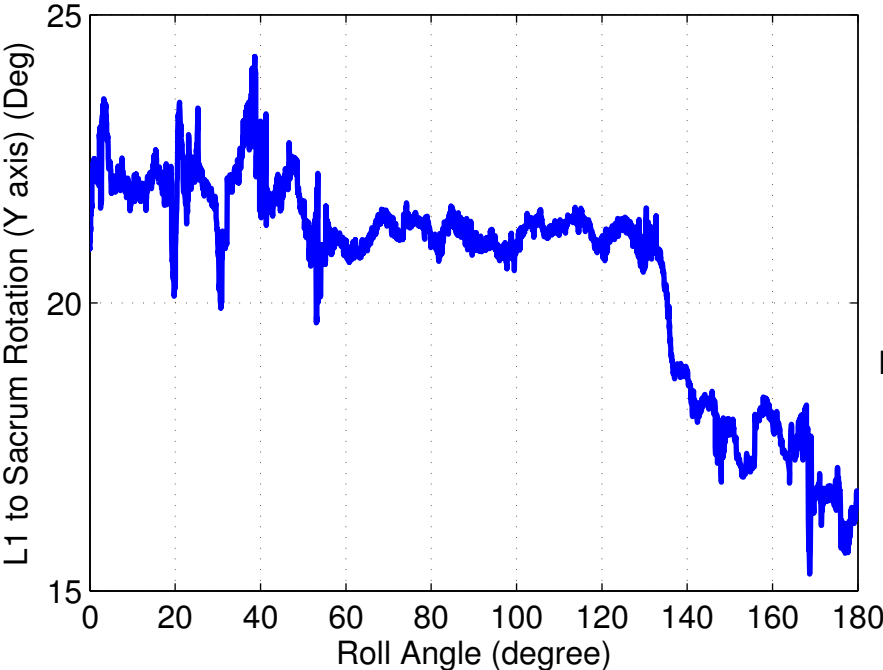


WorldSID in Leading Side



Data Set	Min Roll Ang	Max Roll Ang
 L1 to Sacrum Extension	111.36 (19.8)	122.72 (38.7)

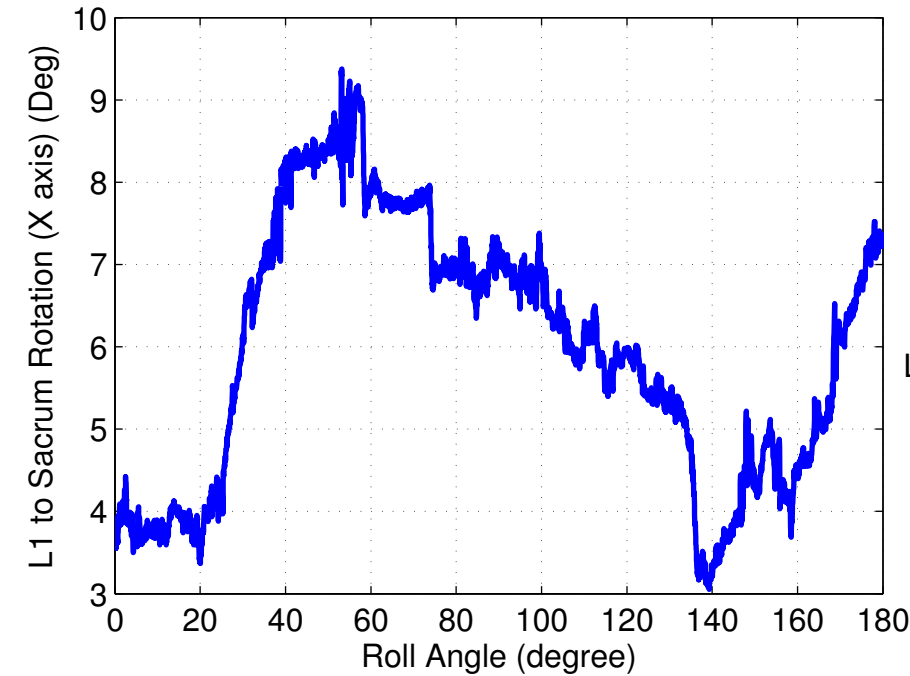
WorldSID in Leading Side



Data Set	Min Roll Ang	Max Roll Ang
 L1 to Sacrum Rotation	15.28 (183.0)	24.28 (38.7)

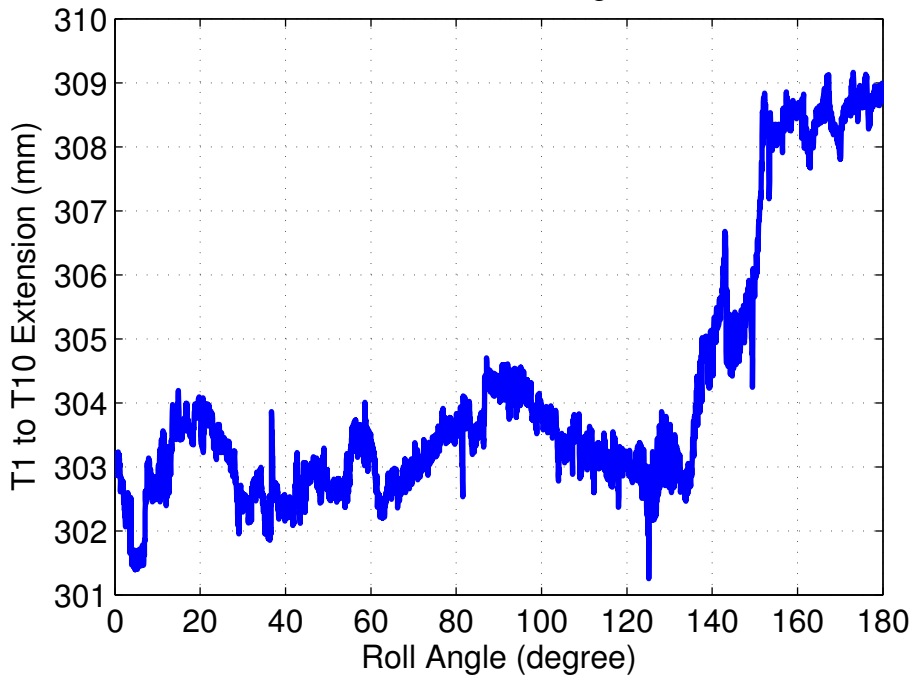


WorldSID in Leading Side



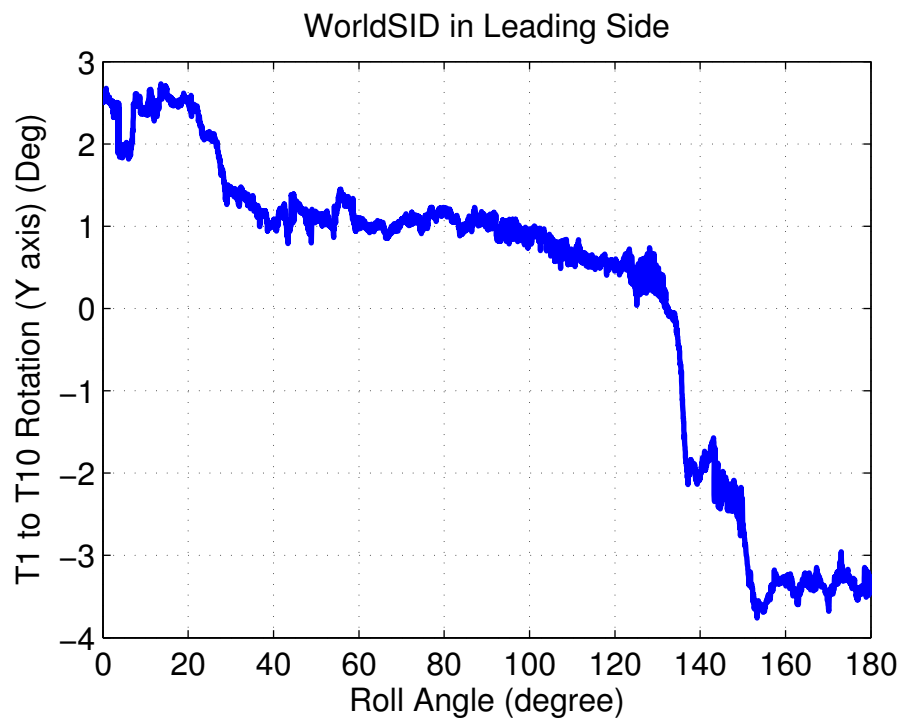
Data Set	Min Roll Ang	Max Roll Ang
	3.05 (139.3)	9.38 (53.2)

WorldSID in Leading Side

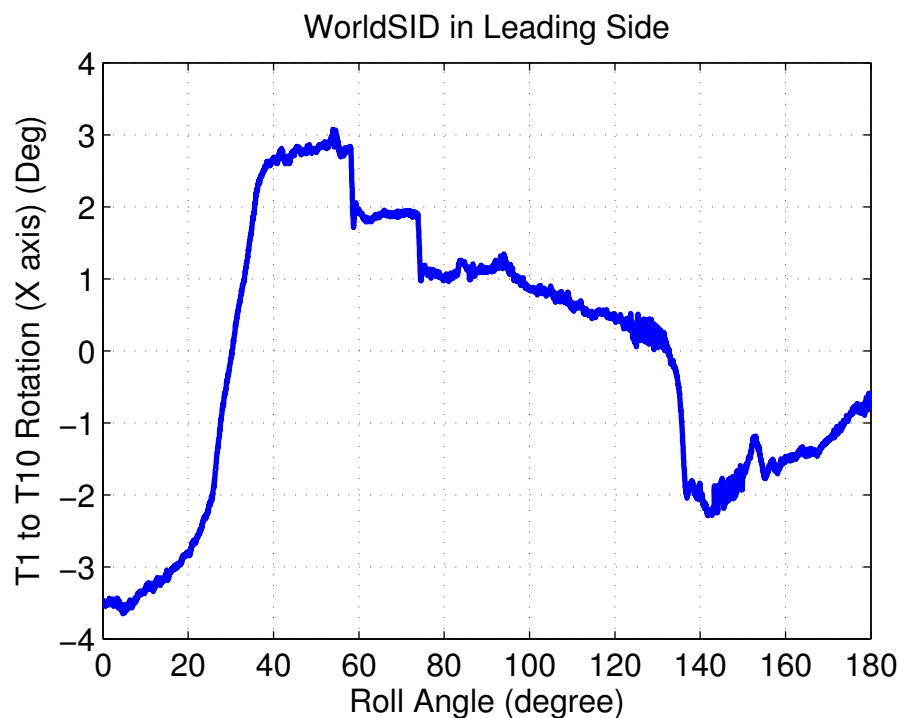


Data Set	Min Roll Ang	Max Roll Ang
	301.25 (125.2)	309.36 (183.0)





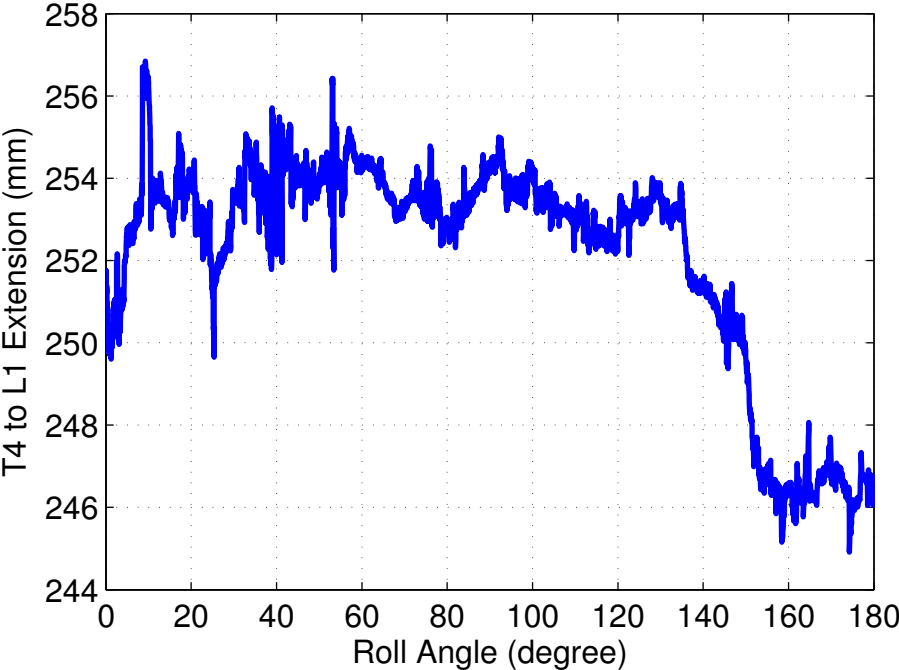
Data Set	Min Roll Ang	Max Roll Ang
T1 to T10 Rotation	-3.87 (181.6)	2.73 (13.6)



Data Set	Min Roll Ang	Max Roll Ang
T1 to T10 Rotation	-3.65 (4.7)	3.07 (54.0)

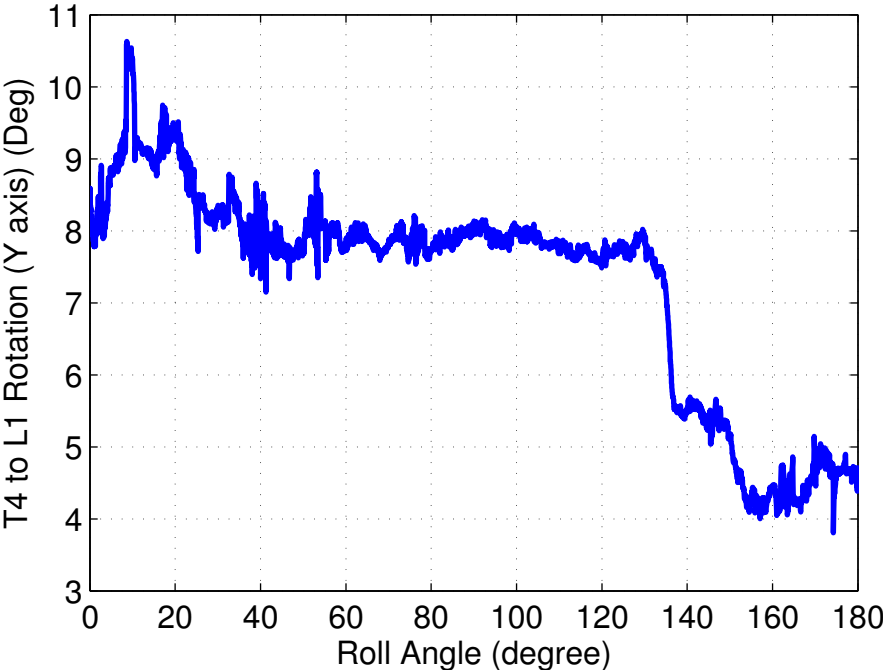


WorldSID in Leading Side



Data Set	Min	Max
	Roll Ang	Roll Ang
T4 to L1 Extension	244.91 (174.3)	256.84 (9.3)

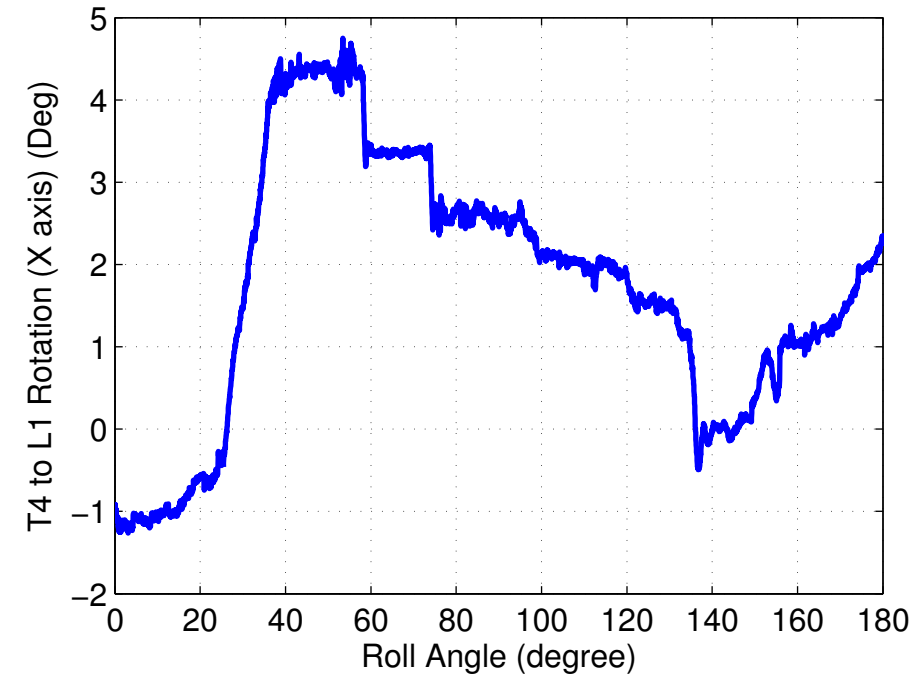
WorldSID in Leading Side



Data Set	Min	Max
	Roll Ang	Roll Ang
T4 to L1 Rotation	3.80 (174.3)	10.63 (8.7)

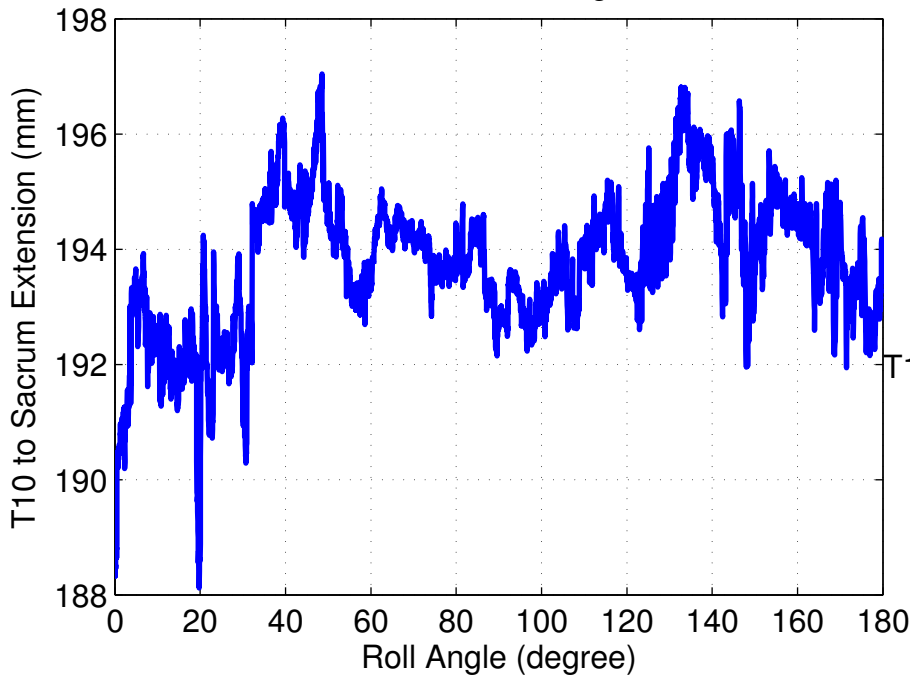


WorldSID in Leading Side



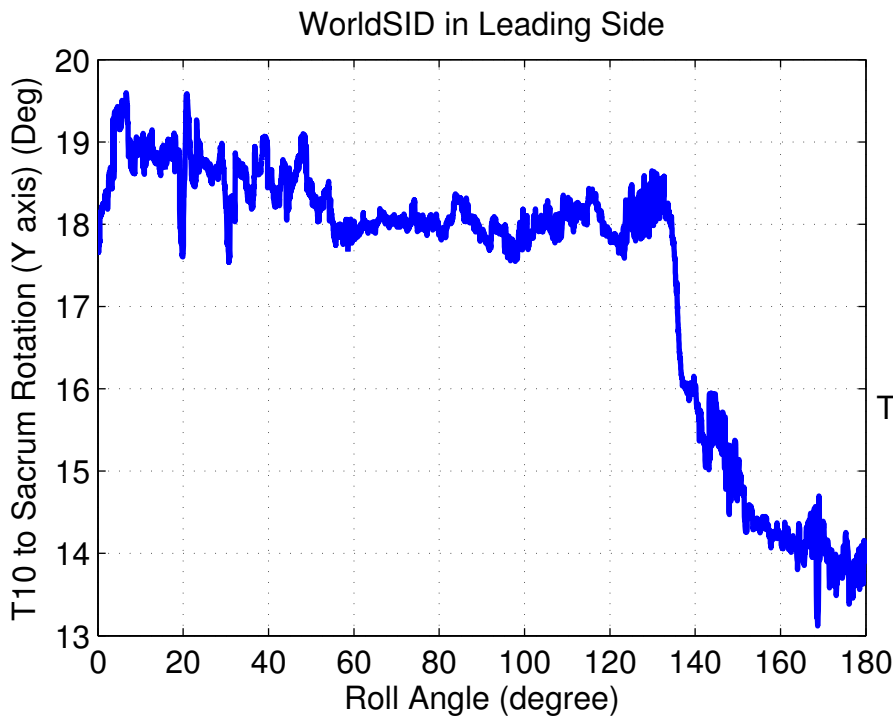
Data Set	Min Roll Ang	Max Roll Ang
T4 to L1 Rotation	-1.26 (3.1)	4.75 (53.4)

WorldSID in Leading Side

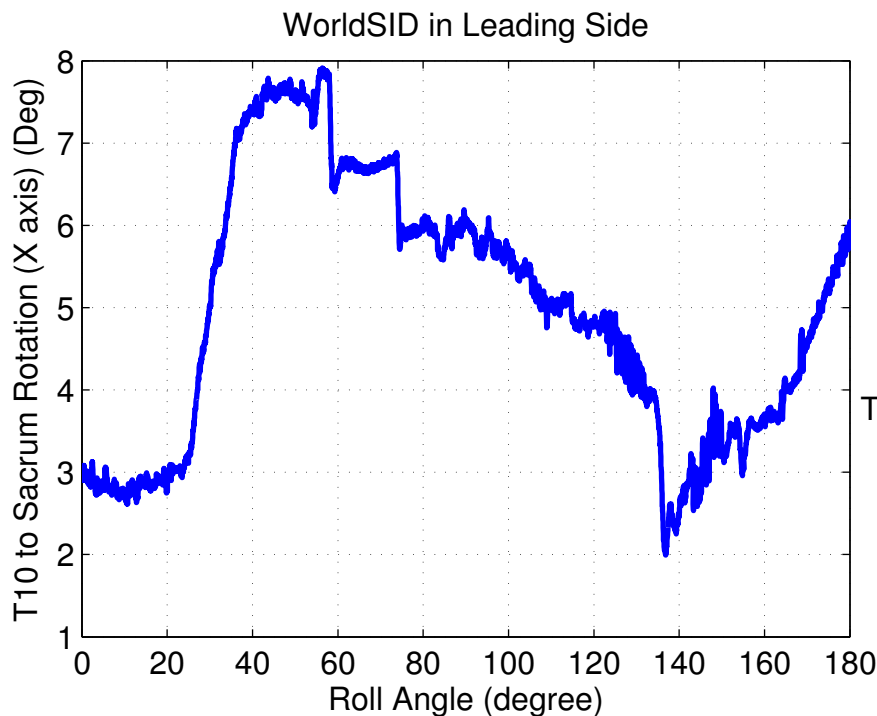


Data Set	Min Roll Ang	Max Roll Ang
T10 to Sacrum Extension	188.12 (19.8)	197.04 (48.6)





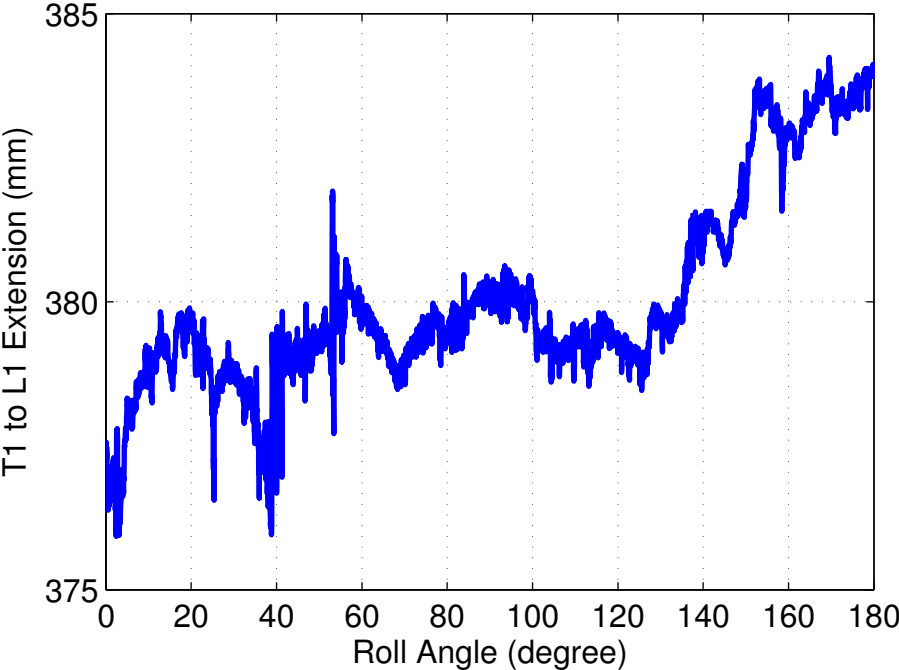
Data Set	Min Roll Ang	Max Roll Ang
	13.12	19.60
T10 to Sacrum Rotation	(168.7)	(6.6)



Data Set	Min Roll Ang	Max Roll Ang
	1.99	7.91
T10 to Sacrum Rotation	(136.9)	(56.4)

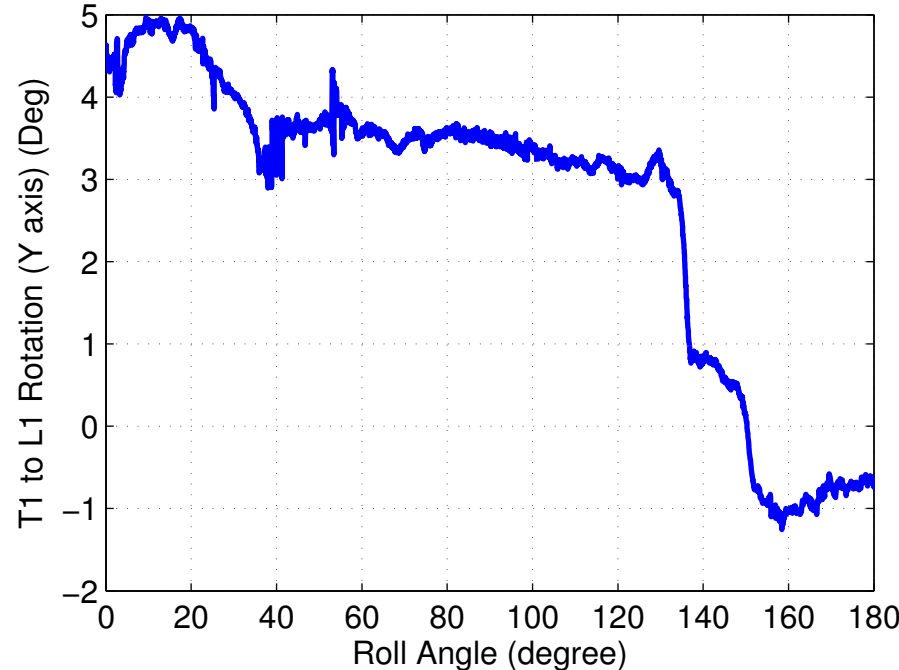


WorldSID in Leading Side



Data Set	Min Roll Ang	Max Roll Ang
T1 to L1 Extension	375.92 (2.4)	384.54 (181.8)

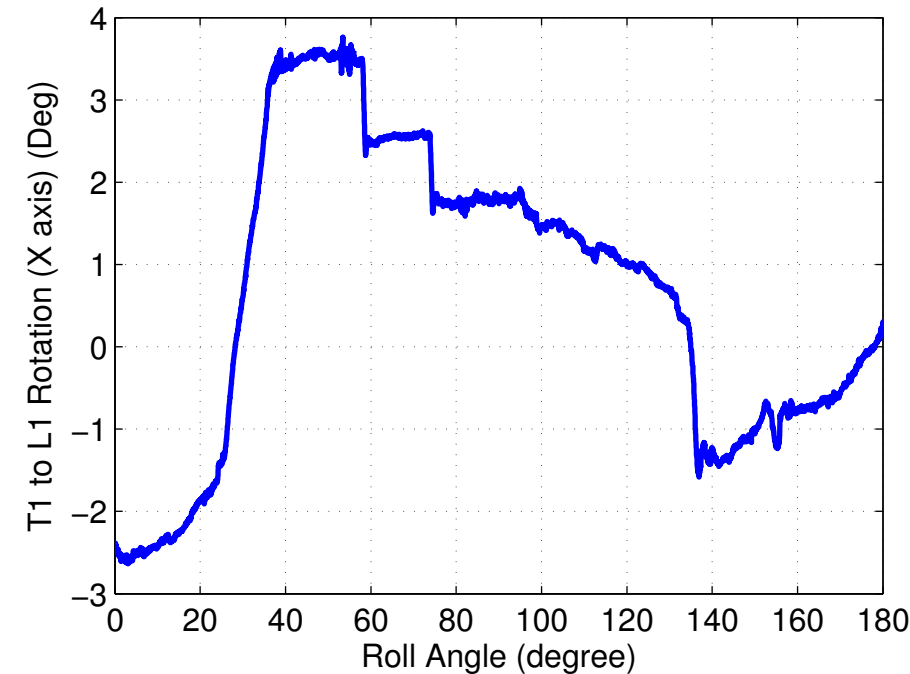
WorldSID in Leading Side



Data Set	Min Roll Ang	Max Roll Ang
T1 to L1 Rotation	-1.25 (158.4)	4.97 (9.4)

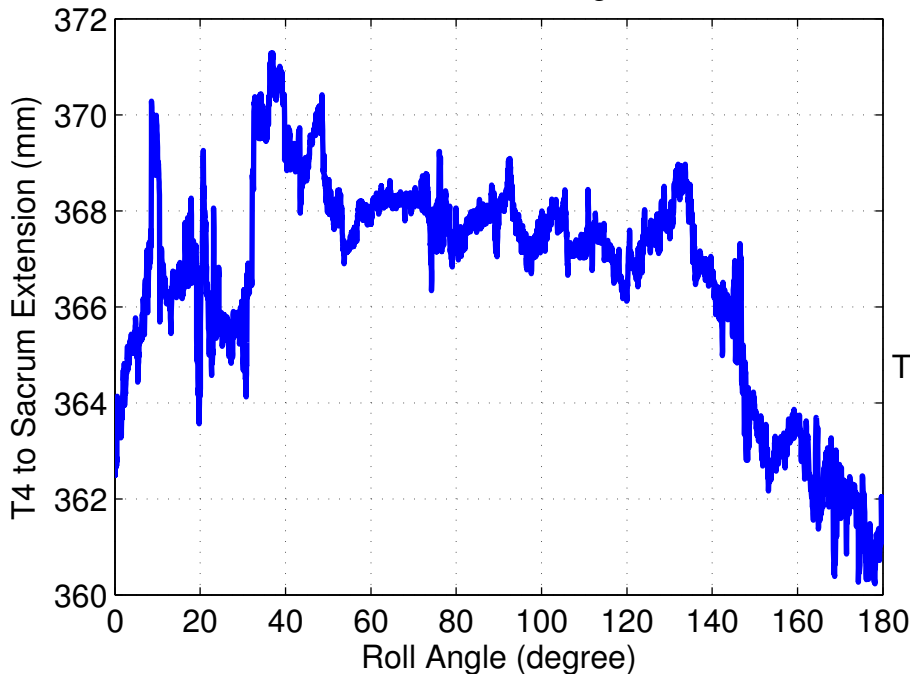


WorldSID in Leading Side



Data Set	Min Roll Ang	Max Roll Ang
T1 to L1 Rotation	-2.64 (3.1)	3.76 (53.4)

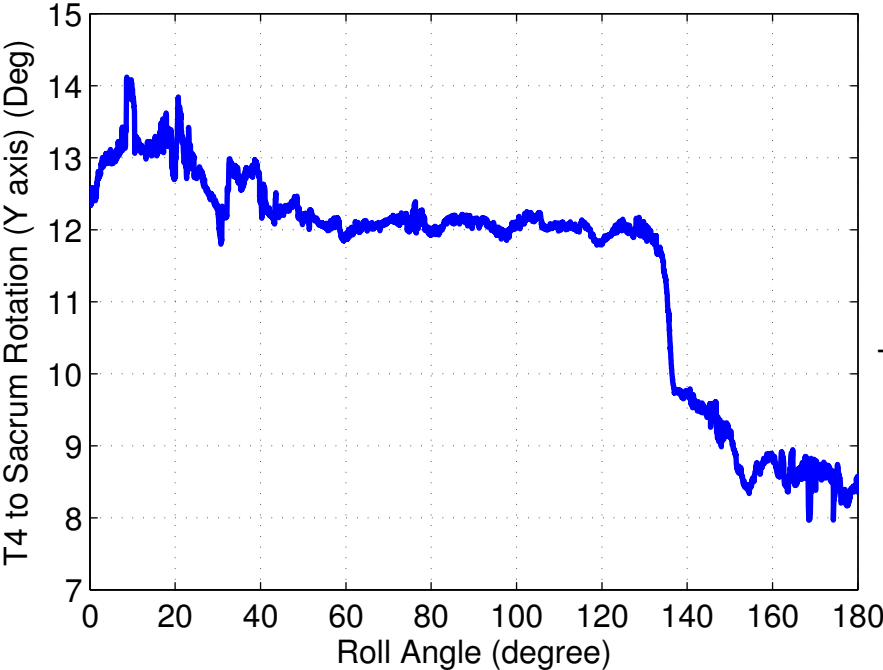
WorldSID in Leading Side



Data Set	Min Roll Ang	Max Roll Ang
T4 to Sacrum Extension	360.13 (180.4)	371.29 (37.0)

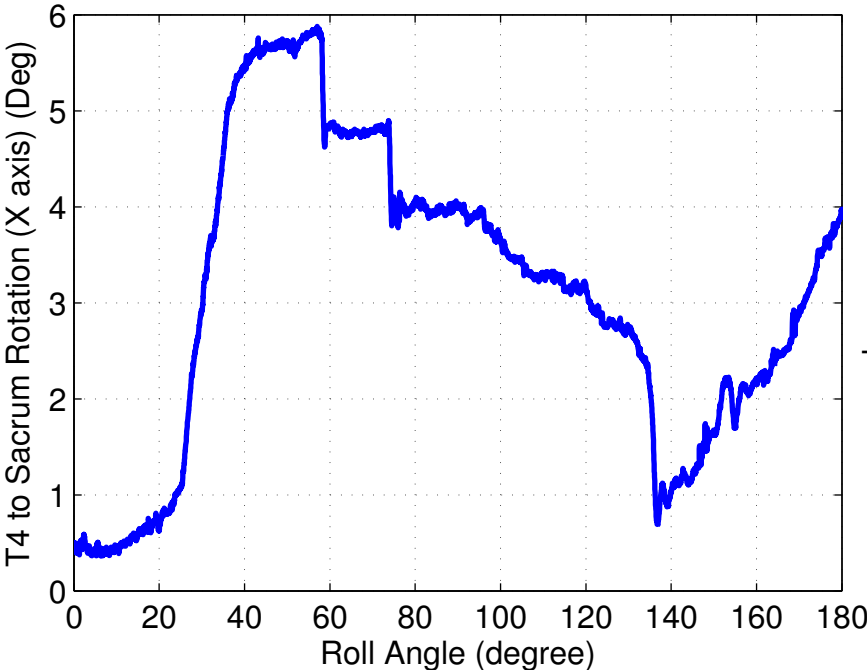


WorldSID in Leading Side



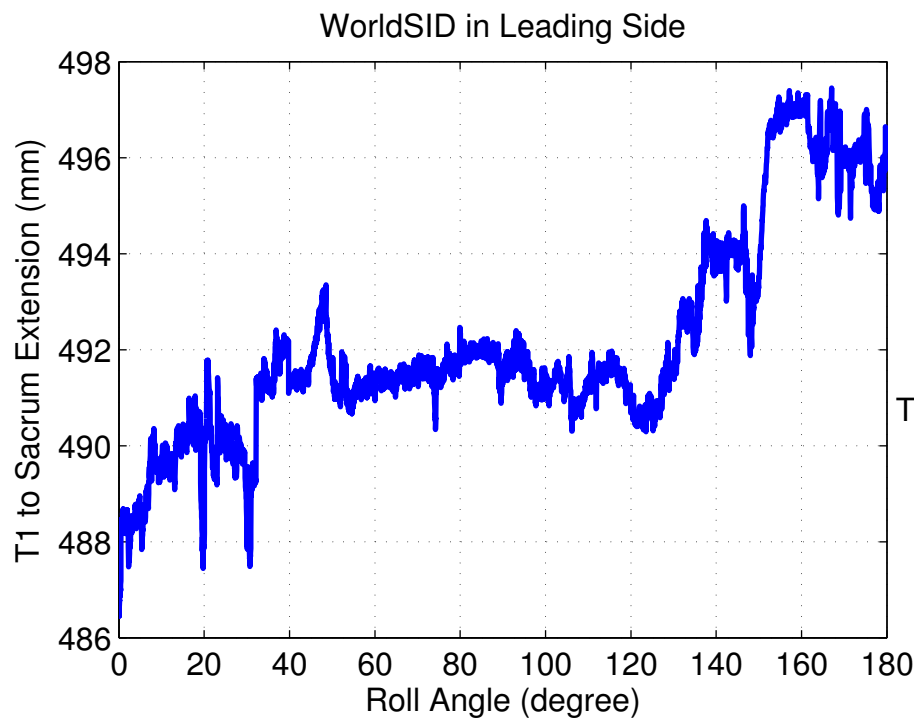
Data Set	Min Roll Ang	Max Roll Ang
T4 to Sacrum Rotation	7.97 (168.5)	14.12 (8.7)

WorldSID in Leading Side

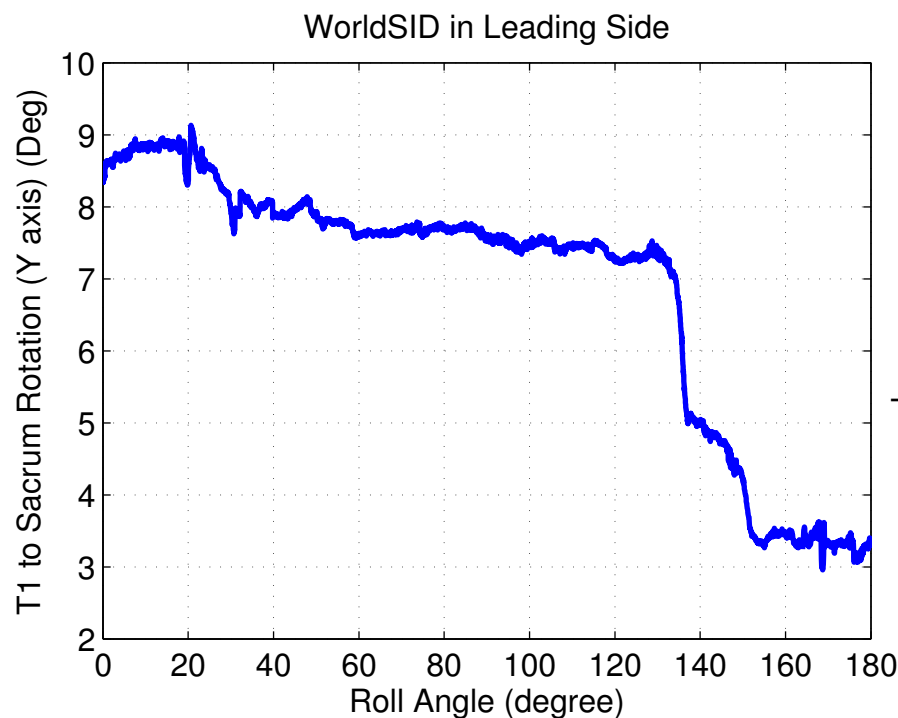


Data Set	Min Roll Ang	Max Roll Ang
T4 to Sacrum Rotation	0.36 (5.3)	5.88 (57.1)



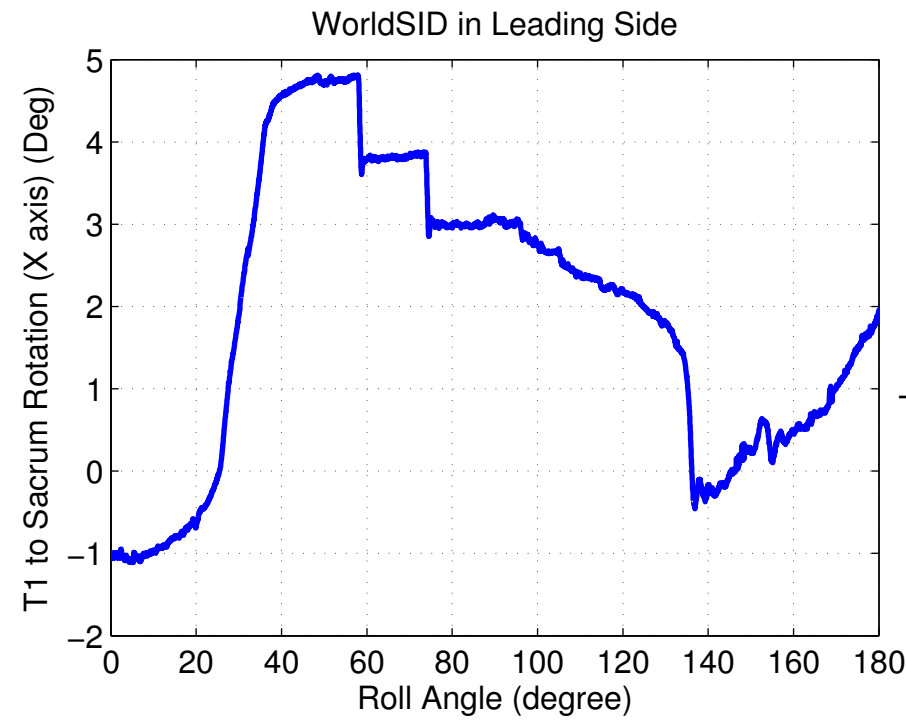


Data Set	Min	Max
	Roll Ang	Roll Ang
 T1 to Sacrum Extension	486.45 (0.1)	497.45 (167.0)

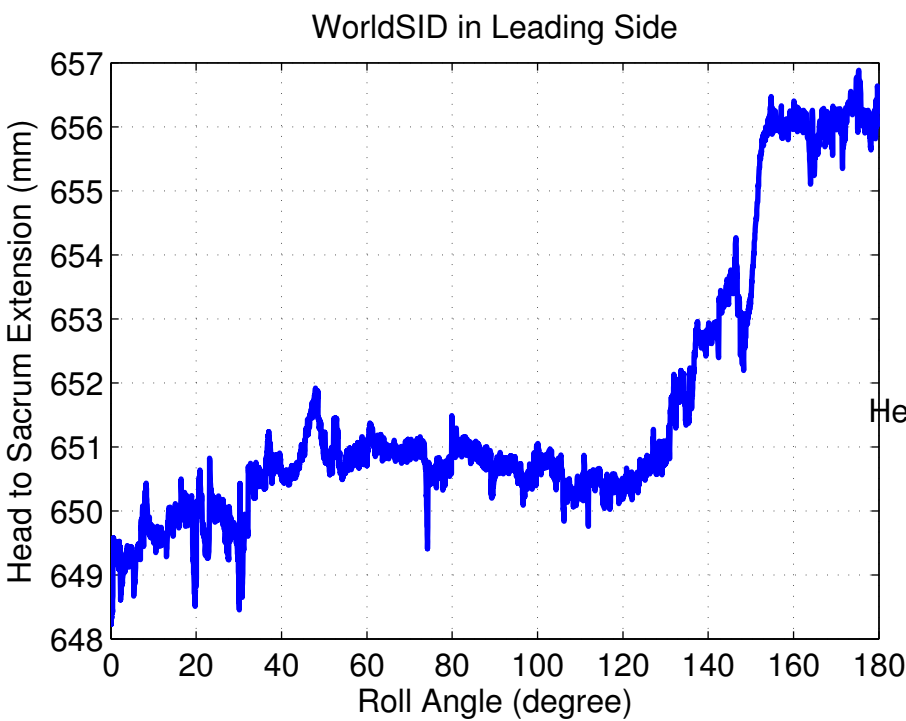


Data Set	Min	Max
	Roll Ang	Roll Ang
 T1 to Sacrum Rotation	2.96 (168.7)	9.13 (20.7)



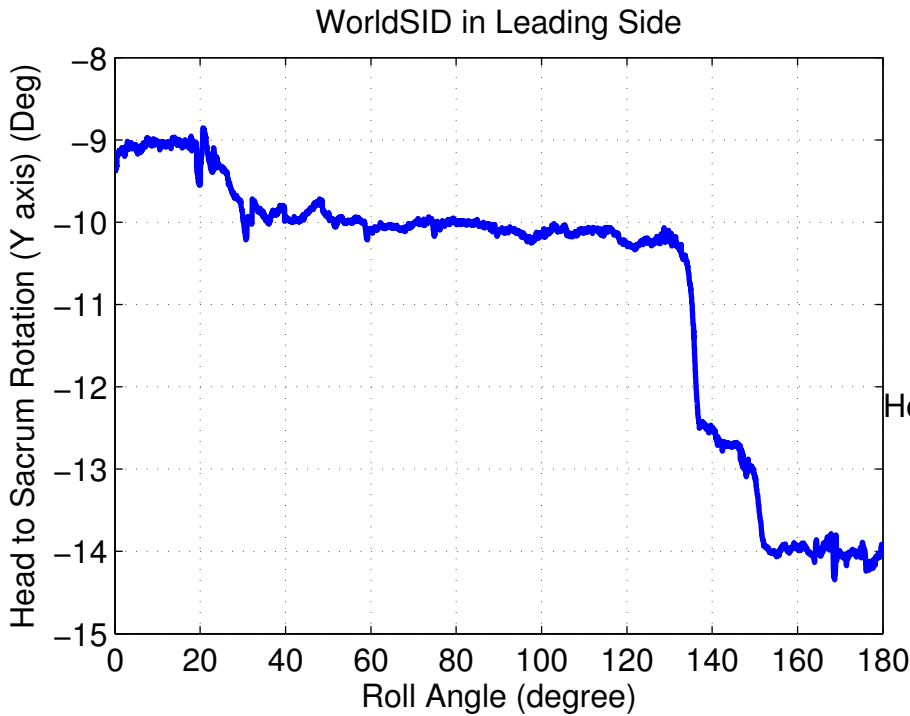


Data Set	Min Roll Ang	Max Roll Ang
T1 to Sacrum Rotation (5.1)	-1.11	4.81

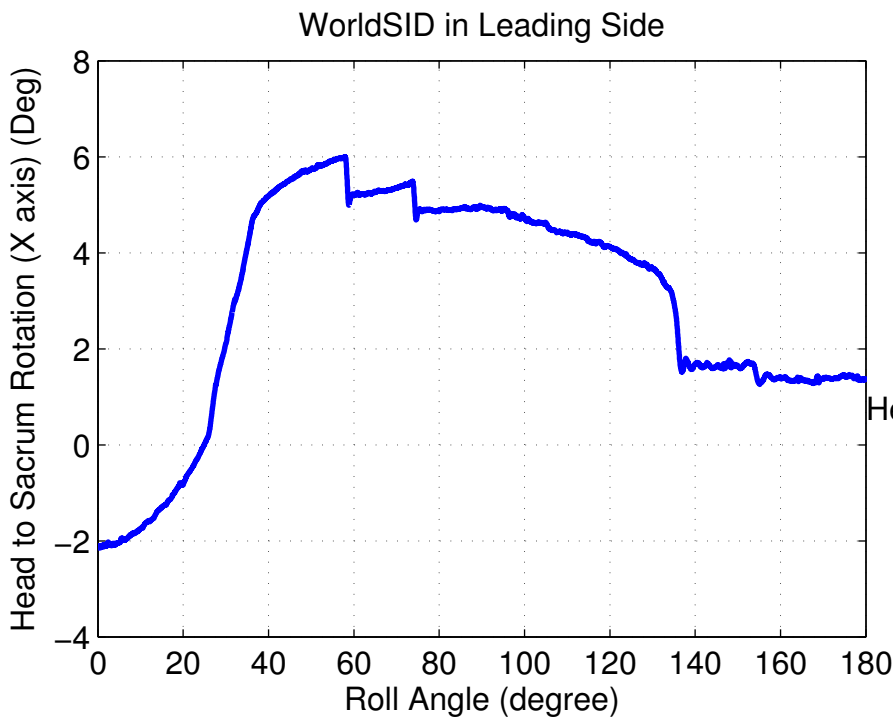


Data Set	Min Roll Ang	Max Roll Ang
Head to Sacrum Extension (650.1)	648.23	657.10





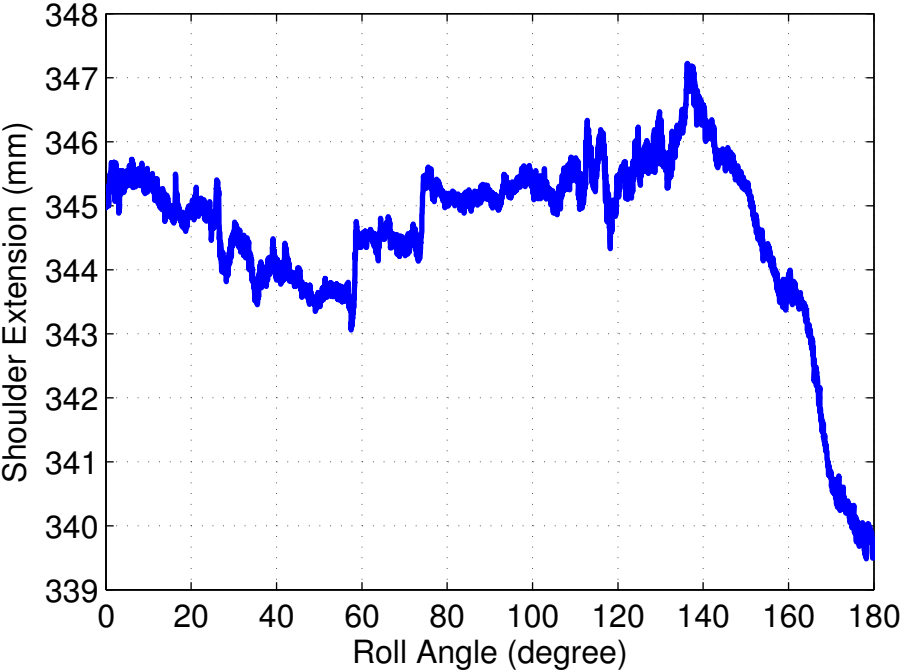
Data Set	Min Roll Ang	Max Roll Ang
	-14.34 (168.7)	-8.85 (20.7)



Data Set	Min Roll Ang	Max Roll Ang
	-2.15 (0.2)	6.00 (57.8)

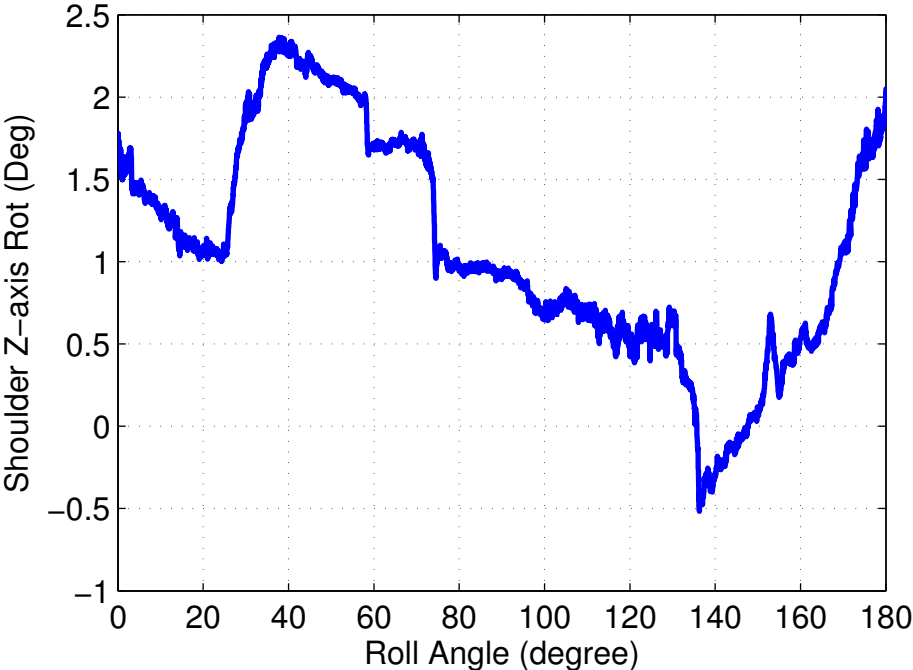


WorldSID in Leading Side



Data Set	Min	Max
	Roll Ang	Roll Ang
Shoulder Extension	338.72 (181.7)	347.22 (136.3)

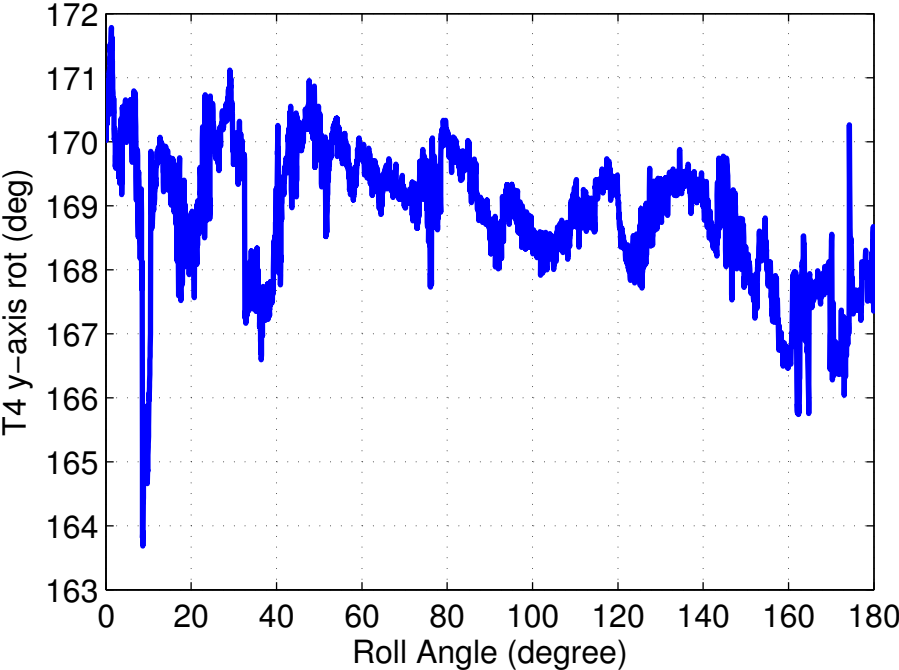
WorldSID in Leading Side



Data Set	Min	Max
	Roll Ang	Roll Ang
Shoulder Z-axis Rot	-0.52 (136.3)	2.85 (182.0)

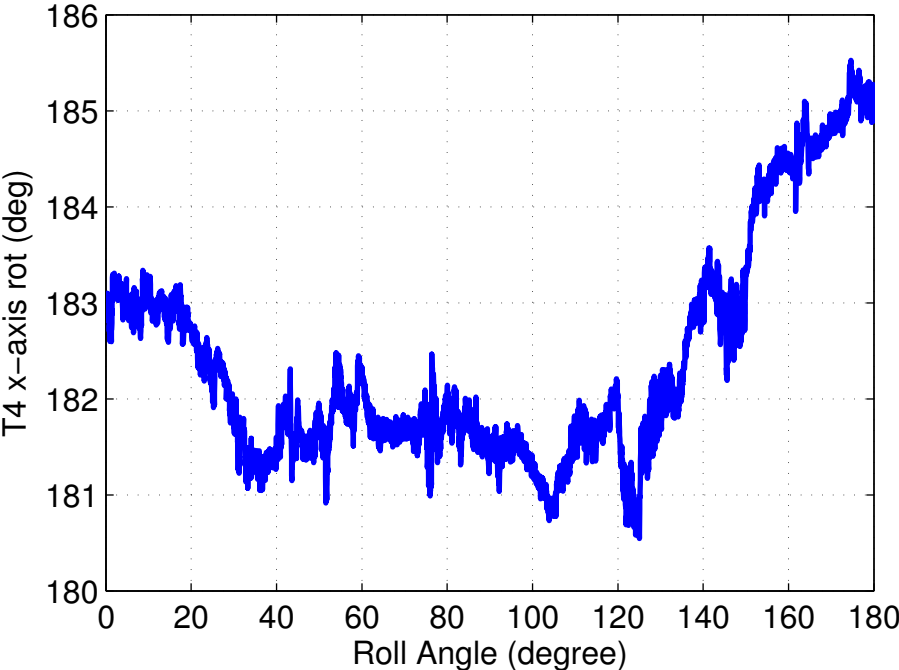


WorldSID in Leading Side



Data Set	Min	Max
	Roll Ang	Roll Ang
T4 y-axis rot	163.68 (8.7)	171.78 (1.3)

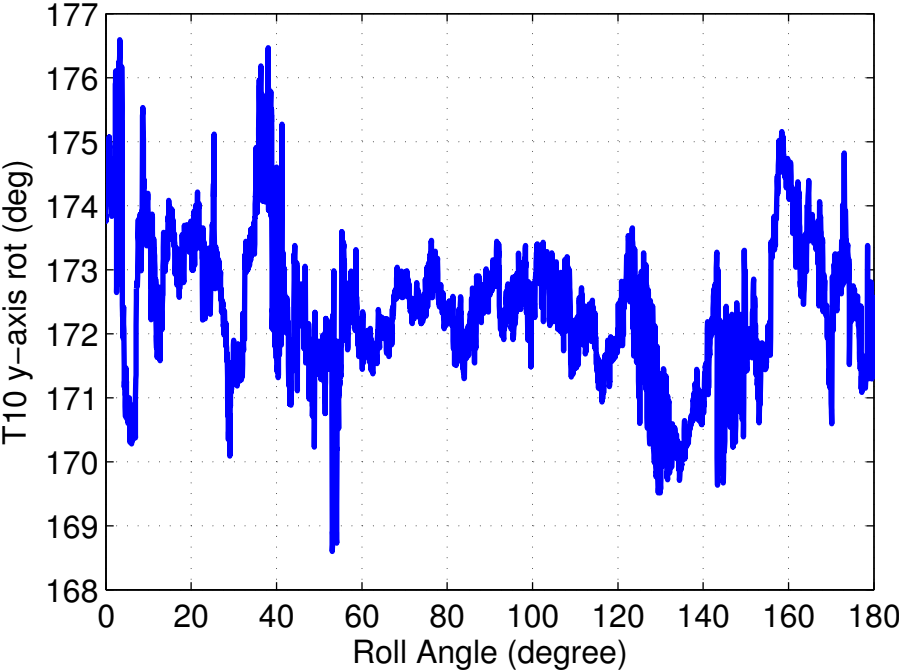
WorldSID in Leading Side



Data Set	Min	Max
	Roll Ang	Roll Ang
T4 x-axis rot	180.55 (125.1)	185.67 (181.8)

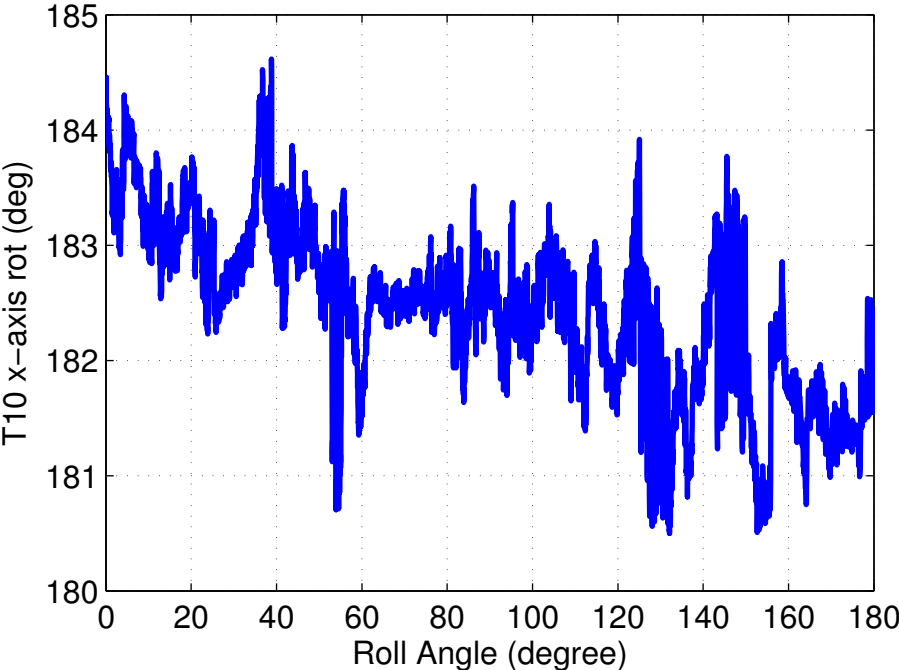


WorldSID in Leading Side



Data Set	Min Roll Ang	Max Roll Ang
 T10 y-axis rot	168.60 (53.1)	176.59 (3.3)

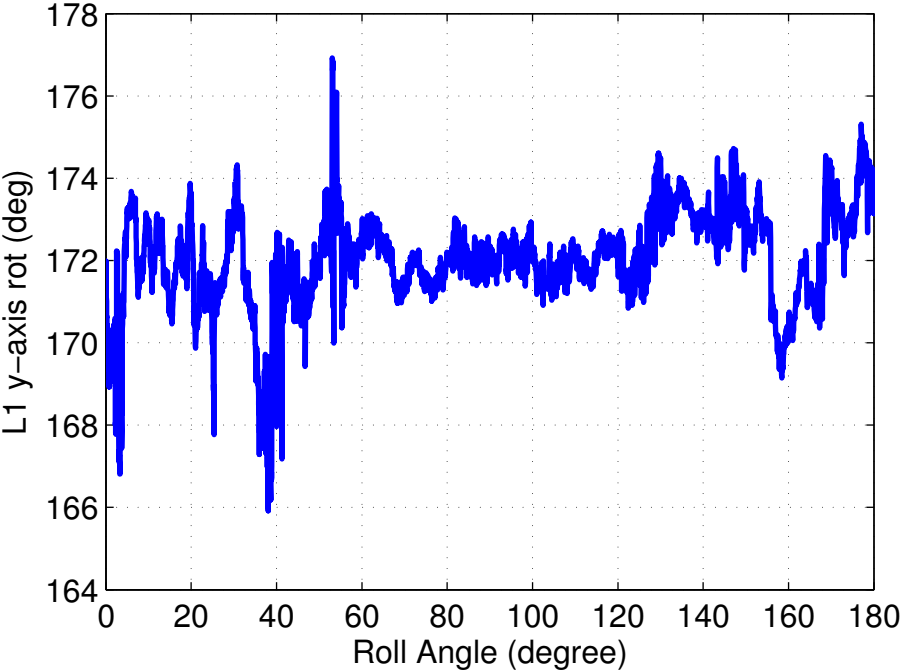
WorldSID in Leading Side



Data Set	Min Roll Ang	Max Roll Ang
 T10 x-axis rot	180.50 (132.1)	184.62 (38.8)

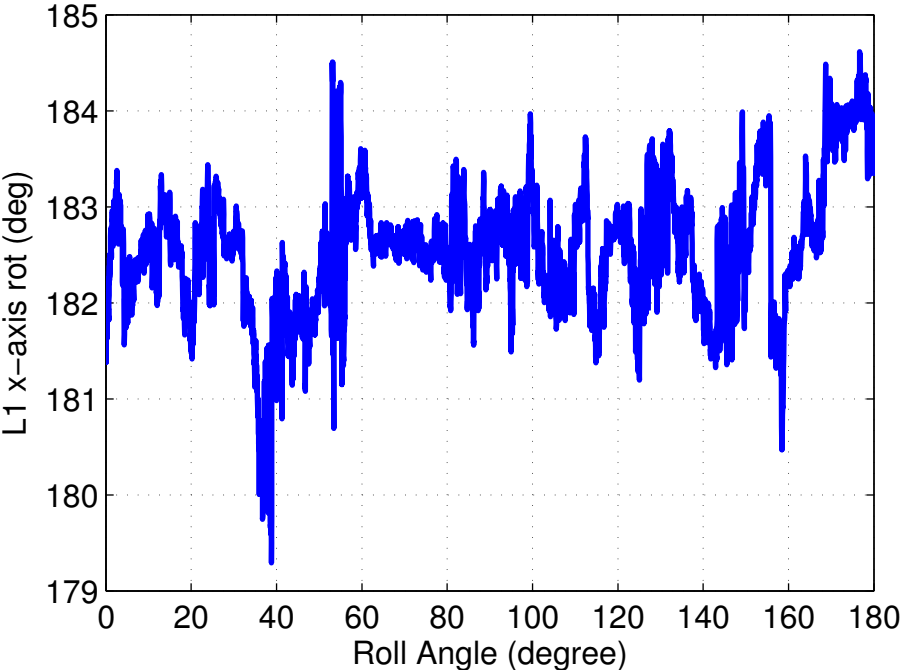


WorldSID in Leading Side



Data Set	Min	Max
	Roll Ang	Roll Ang
 L1 y-axis rot	165.91 (38.1)	176.92 (53.1)

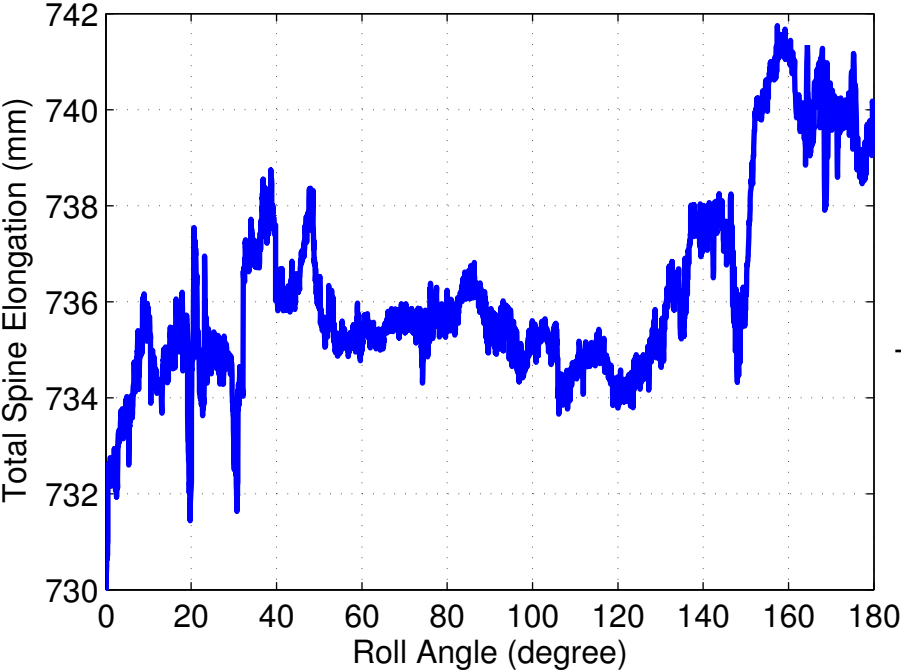
WorldSID in Leading Side



Data Set	Min	Max
	Roll Ang	Roll Ang
 L1 x-axis rot	179.29 (38.8)	184.97 (181.6)



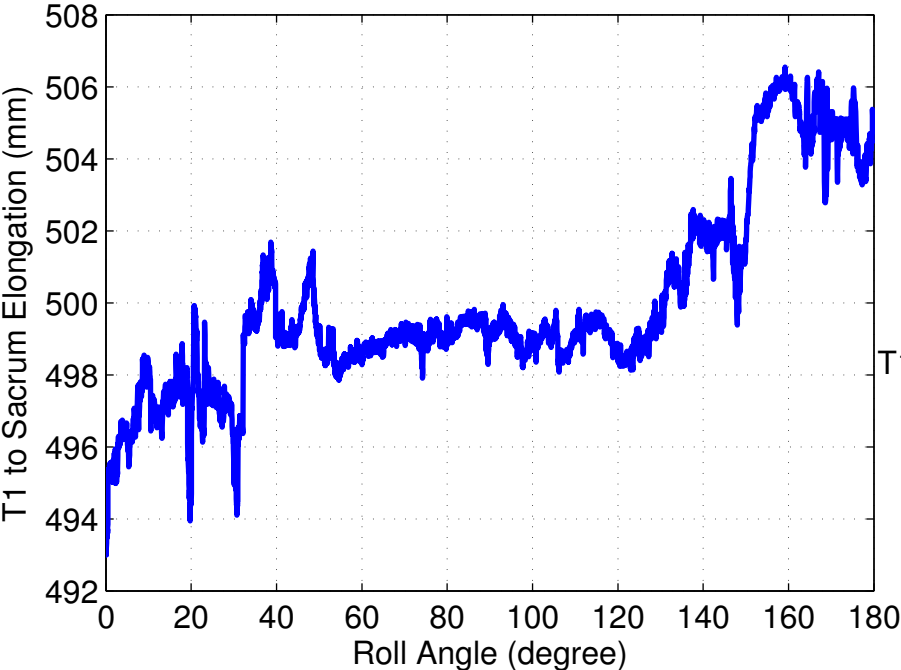
WorldSID in Leading Side



Data Set	Min Roll Ang	Max Roll Ang
	730.04 (0.1)	741.75 (157.4)

Total Spine Elongation

WorldSID in Leading Side



Data Set	Min Roll Ang	Max Roll Ang
	493.00 (0.1)	506.55 (159.2)

T1 to Sacrum Elongation

