CALIFORNIA INSTITUTE OF TECHNOLOGY

EARTHQUAKE ENGINEERING RESEARCH LABORATORY

A COLLECTION OF PROCESSED NEAR-FIELD EARTHQUAKE ACCELEROGRAMS WITH RESPONSE AND DRIFT SPECTRA

BY

LUO-JIA WANG, QUN GU, AND W. D. IWAN

REPORT NO. EERL 96-05

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A number of particularly important earthquake accelerograms were measured by instruments that were located in the Near-Field region of several recent earthquakes. For a strike-slip or a thrust fault earthquake, this region is taken to be the area within and immediately adjacent to the surface trace or the surface prediction of the fault rupture plane and its extension to the earth's surface. Such accelerograms are termed near-field earthquake accelerograms. They possess the following features that differ from other earthquake accelerograms:

- distinctive pulse-like time histories,
- high peak velocities, and
- high ground displacements.

These features of near-field ground motion have not yet been well documented and are generally not considered in seismic design. It has been shown, however, that they can place very serious demand on structures located in the near-field region of an earthquake [1].

This report presents uniformly processed data for 12 near-field earthquake accelerograms obtained from four recent earthquakes. The results are presented in the following format:

- time histories of acceleration, velocity, and displacement rotated to east-west, north-south, and maximum velocity directions,
- horizontal particle trajectories,
- Response Spectra for the east-west, north-south, and maximum velocity directions, and
- Drift Demand Spectra for the east-west, north-south, and maximum velocity directions.

Tables 1-4 summarize the relevant information for the earthquakes and near-field accelerograms in this report. Plots of time histories, horizontal particle trajectories, Response Spectra and Drift Demand Spectra are presented in the figures following Table 4.

All accelerograms were uniformly corrected using the processing scheme developed by Iwan and Chen [2]. This includes appropriate instrument correction according to the instrument type and baseline correction without band-pass filtering.

The time history, Response Spectrum and Drift Demand Spectrum for the north-south component of the El Centro (ELC) accelerogram obtained in the 1940 Imperial Valley earthquake are included in Appendix 1 for purposes of comparison. As shown by their response and Drift Demand Spectra, all 12 earthquake accelerograms featured in this report place much higher demands on the response and interstory drift of structures than does the standard ELC ground motion. This suggests that the widely used ELC accelerogram may be inadequate for some design purposes.

All data processing, response and Drift Demand Spectral computations, and plotting were performed using a Matlab-based package [4].

REFERENCES

1. Iwan, W. D., "Near-Field Considerations in Specification of Seismic Design Motions for Structure," Proceedings of the 10th European Conference on Earthquake Engineering, Vienna, Austria, August 28-September 2, 1994.

2. Iwan, W. D. and X. Chen, "Important Near-Field Ground Motion Data from the Landers Earthquake," Proceedings of the 10th European Conference on Earthquake Engineering, Vienna, Austria, August 28-September 2, 1994.

3. Iwan, W. D., "Drift Demand Spectra for selected Northridge Sites," EERL 95-07, Earthquake Engineering Research Laboratory, California Institute of Technology, Pasadena, December, 1995.

4. Wang, L. J., "Processing of Near-Field Earthquake Accelerograms," EERL 96-EERL 96-04, Earthquake Engineering Research Laboratory, California Institute of Technology, Pasadena, September 1996.

Table 1. Twelve selected near-field earthquake accelerograms presented in this report

Station Name	Tick	Earthquake	Epic. Dist. (km)	Soil Condition	Page
Lucerne Valley Station	LUC	Landers	42		6
Rinaldi Receiving Station	RRS	Northridge	10	alluvium	17
Sylmar Converter Station	SCS	Northridge	12	alluvium	28
Sylmar Converter Station - East	SCE	Northridge	13	sediment rock	39
Sylmar County Hospital Parking Lot	SCH	Northridge	16	alluvium	50
Arleta Nordhoff Avenue Fire Station	ARL	Northridge	10	deep alluvium	61
Newhall, LA County Fire Station	NHL	Northridge	20	alluvium	72
Santa Monica City Hall Grounds	SMC	Northridge	23	alluvium	83
Pardee Station	PAR	Northridge	41		94
Takatori Station	TAK	Hyogo-Ken-Nanbu	14	soft soil	105
Kobe Station	KOB	Hyogo-Ken-Nanbu	17	soft soil	116
Erzincan Station	ERZ	Erzincan	11	deep alluvium	127

Table 2. Four recent earthquakes from which near-field earthquake accelerograms were obtained

Earthquake	Date	Magnitude (M_w)	Fault Type
Landers, USA	July 24, 1992	7.5	Strike-Slip
Northridge, USA	January 17, 1994	6.7	Blind Thrust
Hyogo-Ken-Nanbu, Japan	January 17, 1995	6.9	Strike-Slip
Erzincan, Turkey	March 13, 1992	6.9	Strike-Slip

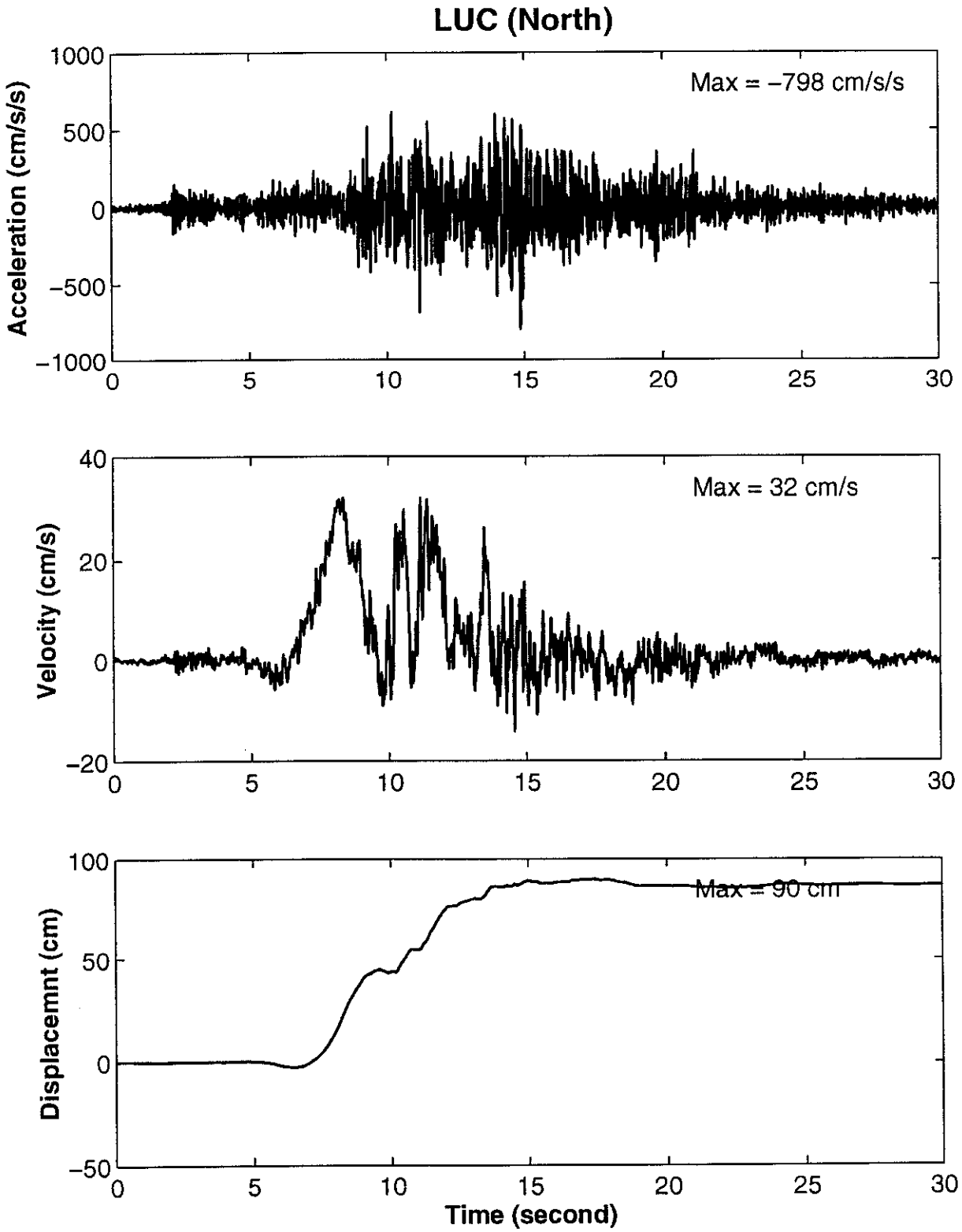
Table 3. Parameters of strong motion accelerographs

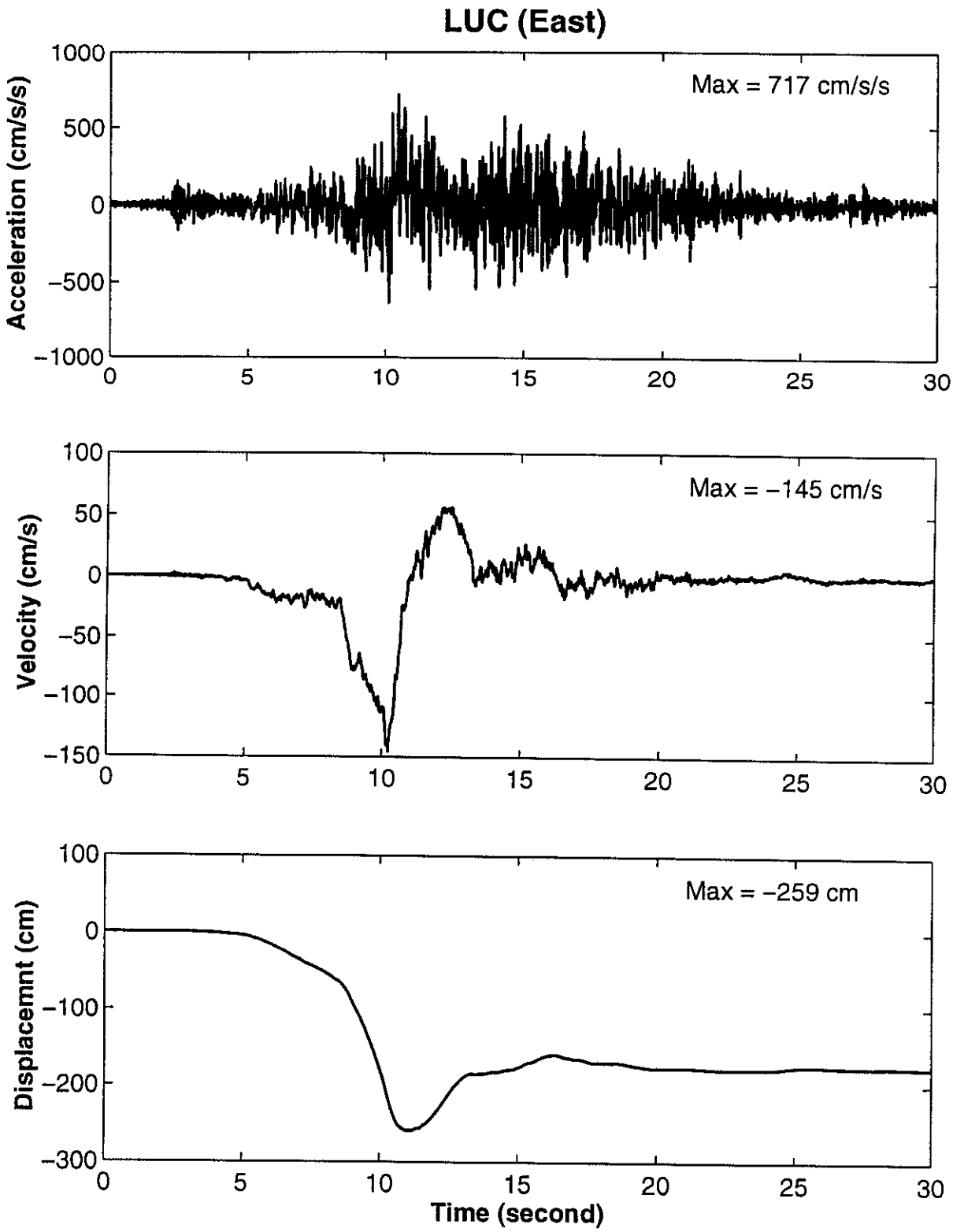
Station	Owner	Instrument Type	Time Step (second)	Sensor Directions	Frequency (Hz)	Damping Ratio	Baseline Parameters
LUC	SCE	SMA-2	1/256	N00E N85W	0.038 0.038	0.59 0.59	
RRS	LADWP	SMA-1	0.005	N42W S48W	0.040 0.039	0.58 0.61	0.5,0,8,2 0.5,0,6.5,2
SCS	LADWP	CRA-1	0.005	N52E S38E	0.019 0.020	0.64 0.65	0.5,0,12.5,3 0.5,0,11.5,3
SCE	LADWP	SMA-1	0.005	N18E N72W	0.040 0.038	0.60 0.60	0.5,0,8,2 0.5,0,8,2
SCH	CDMG	SMA-1	0.005	N90E N00E	0.0368 0.0375	0.60 0.60	1,0,15,2 1,0,11,3
ARL	CDMG	SMA-1	0.005	N90E N00E	0.0377 0.0397	0.61 0.61	1,0,20,1 1,0,26,1
NHL	CDMG	SMA-1	0.005	N90E N00E	0.0383 0.0388	0.56 0.58	2,0,13,0 0.5,1,16,2
SMC	CDMG	SMA-1	0.005	N90E N00E	0.0383 0.0375	0.57 0.60	5,0,15,2 4.5,0,25,0
PAR	SCE	SMA-2	0.005	S00E N90E	0.0392 0.0397	0.73 0.73	3,3,13,2 3,3,12.92,2
TAK	RTRI		0.01	N90E N00E	0.100 0.100	0.70 0.70	5,0,3,1 5,0,3,1
KOB	JMA		0.02	N90E N00E	0.100 0.100	0.70 0.70	4.5,0,20,1 4.5,0,20,1
ERZ	ERD	SMA-1	0.01	N90E N00E	0.040 0.040	0.70 0.70	1.95,3,6.7,3 1.95,3,6.7,3

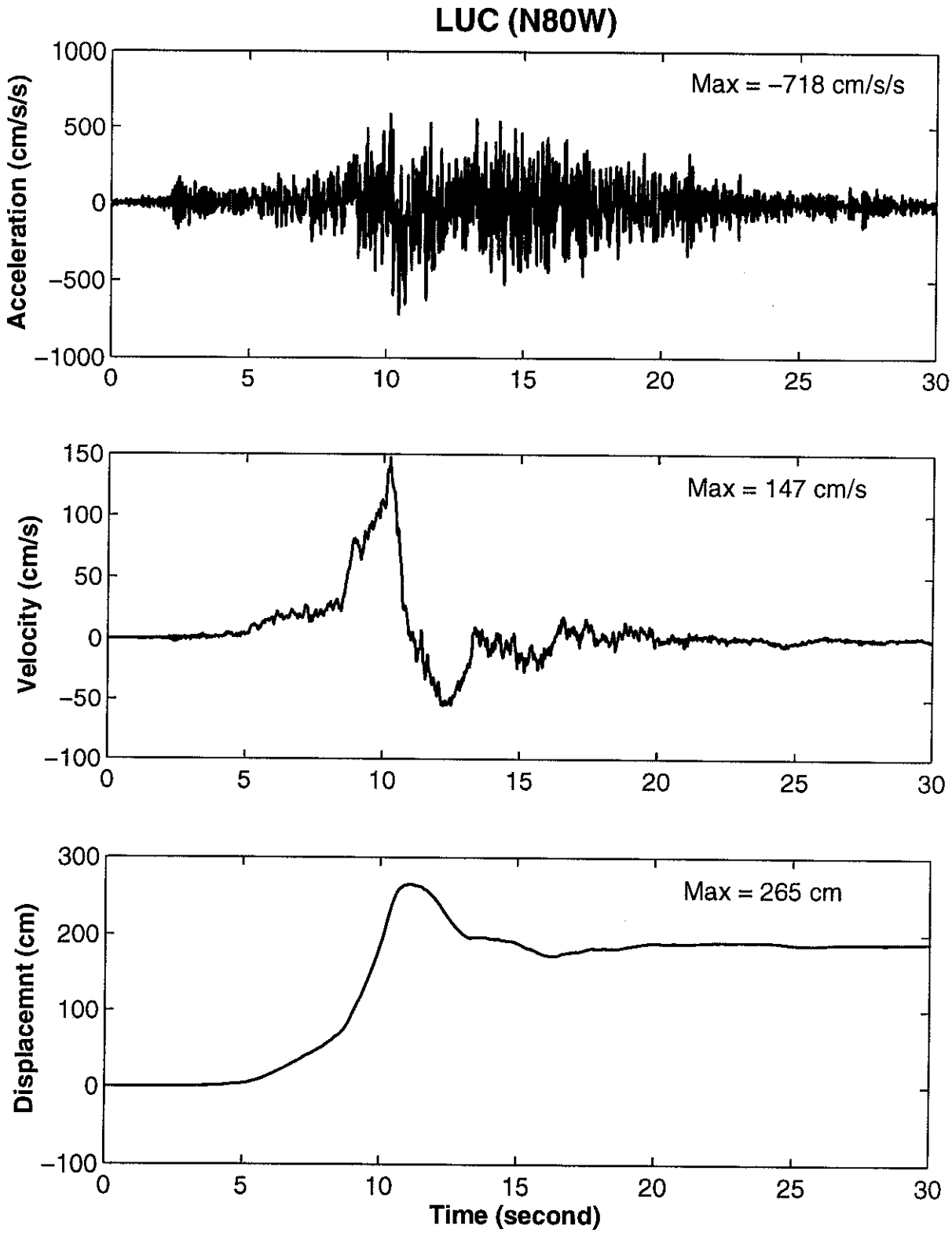
Table 4. Peak values of acceleration, velocity, and displacement for selected accelerograms

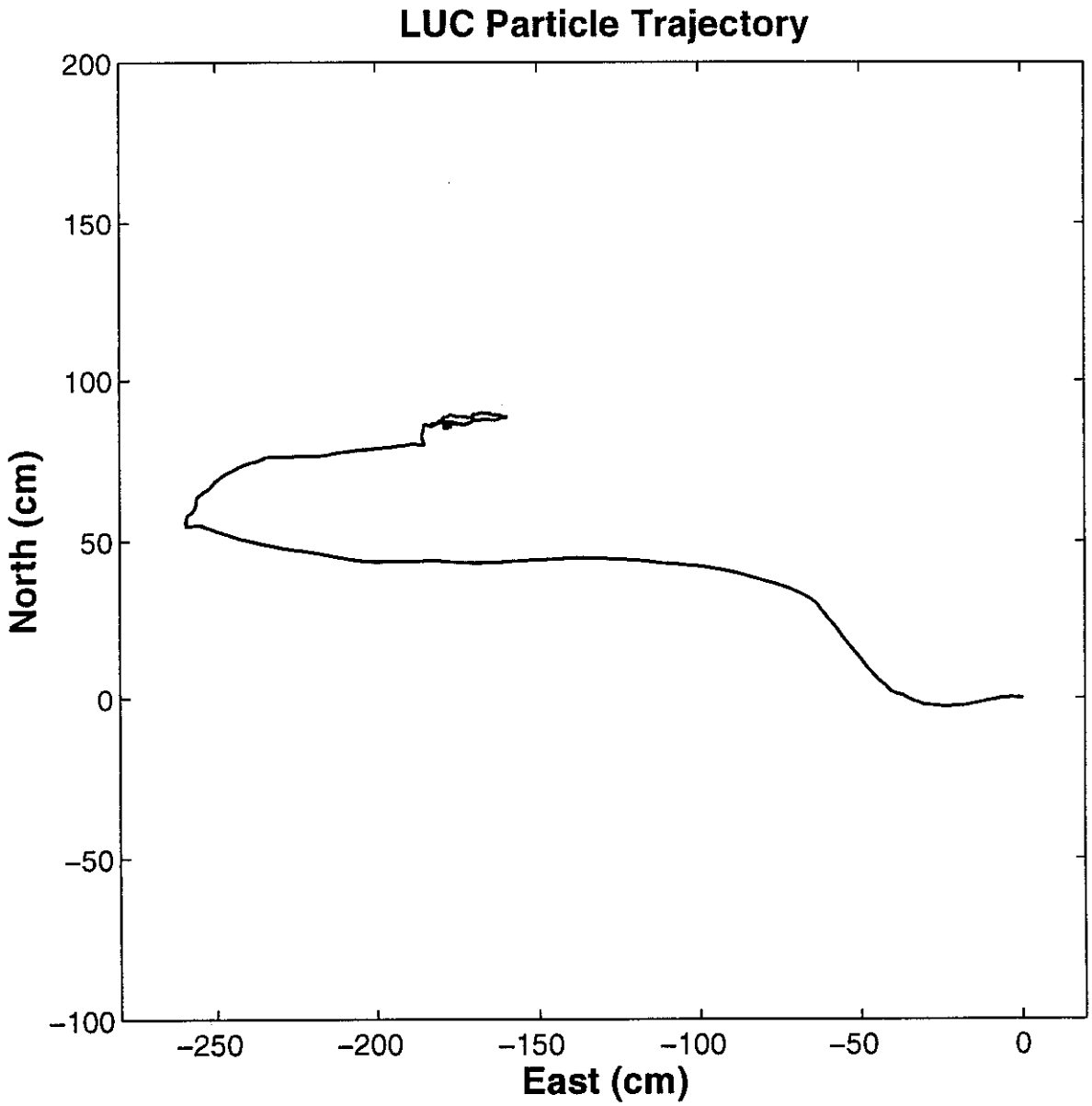
	East			North			Maximum Velocity Direction			
Station	PA (cm/s/s)	PV (cm/s)	PD (cm)	PA (cm/s/s)	PV (cm/s)	PD (cm)	Component	PA (cm/s/s)	PV (cm/s)	PD (cm)
LUC	717	-145	-259	-798	32	90	N80W	-718	147	265
RRS	555	-102	-74	805	-159	-59	S32W	-873	186	61
SCS	563	-77	45	761	-134	43	S16W	-690	138	-53
SCE	460	-67	41	737	-112	-30	S22W	-812	119	-39
SCH	592	-81	-31	863	-136	-48	S10W	-848	138	49
ARL	336	-40	17	299	-24	-16	S80W	-340	40	-15
NHL	-484	-75	22	581	-98	39	S37W	-731	121	-34
SMC	-855	41	-17	-396	27	-13	N89E	-855	41	-17
PAR	305	46	-42	-485	-60	-18	S17W	463	62	22
TAK	637	-124	30	600	121	-39	N49W	721	155	-45
KOB	607	-76	-17	-802	92	26	N35W	-838	107	29
ERZ	-482	-90	-47	390	-110	-40	S31W	-433	126	52

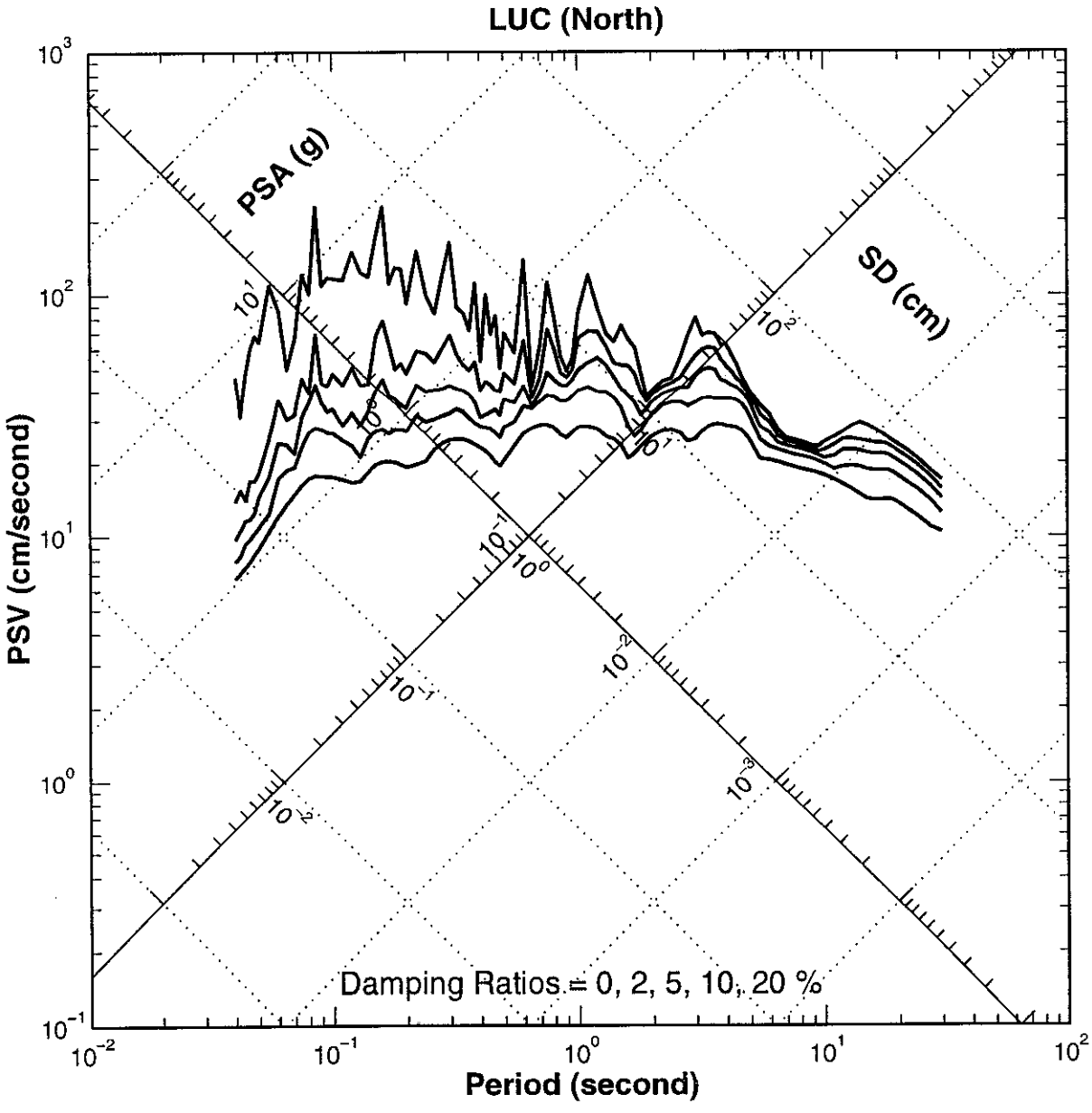
LUCERNE VALLEY STATION (LUC)

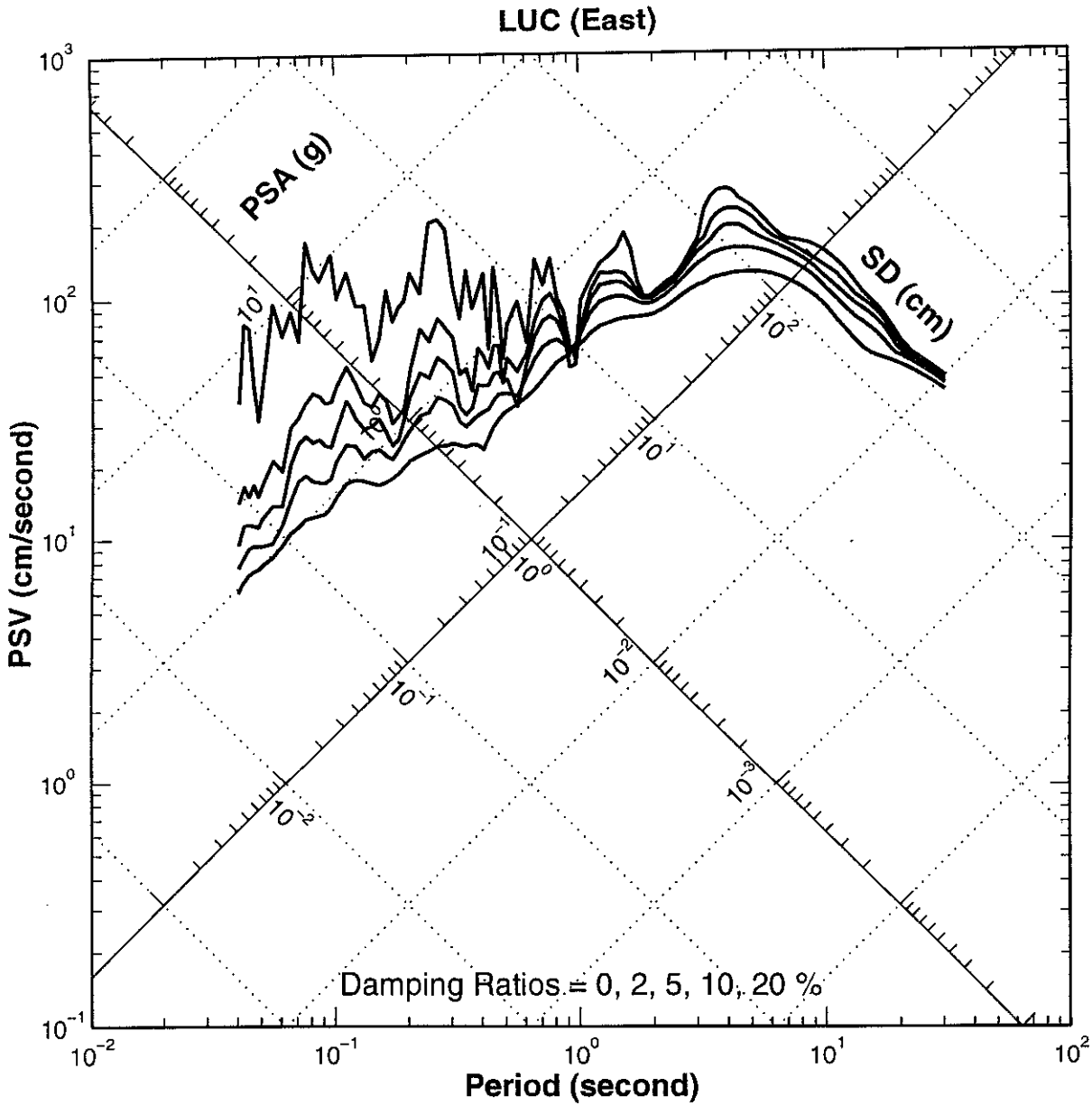

LUC (North)
Max = −798 cm/s/s
Acceleration (cm/s/s)
1000
500
0
−500
−1000
0
5
10
15
20
25
30
Max = 32 cm/s
Velocity (cm/s)
40
20
0
−20
Max = 90 cm
Displacemnt (cm)
100
50
0
−50
Time (second)

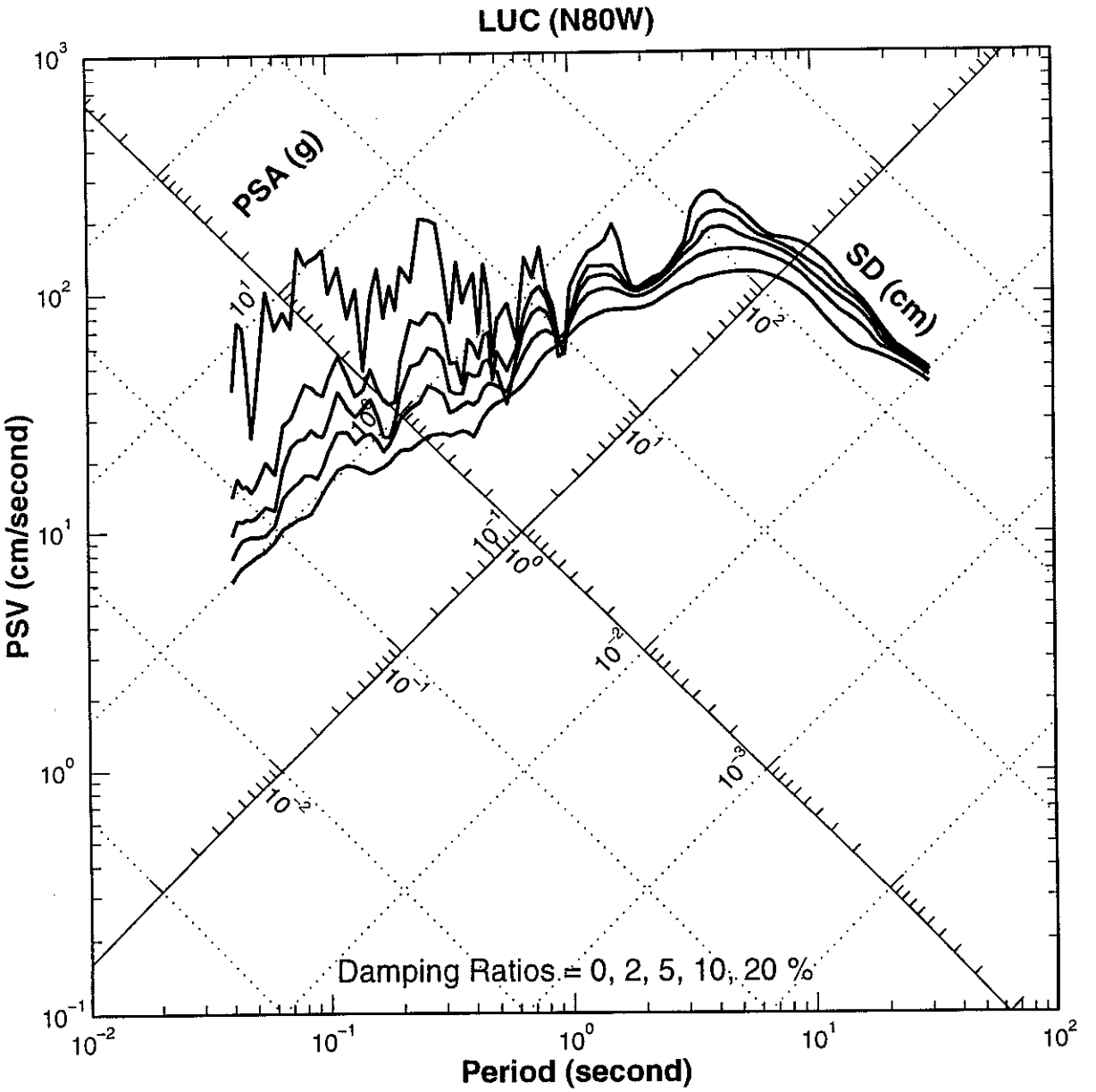

LUC (East)
Acceleration (cm/s/s)
Max = 717 cm/s/s
1000
500
0
−500
−1000
0
5
10
15
20
25
30
Velocity (cm/s)
Max = −145 cm/s
100
50
0
−50
−100
−150
Displacemnt (cm)
Max = −259 cm
100
0
−100
−200
−300
Time (second)

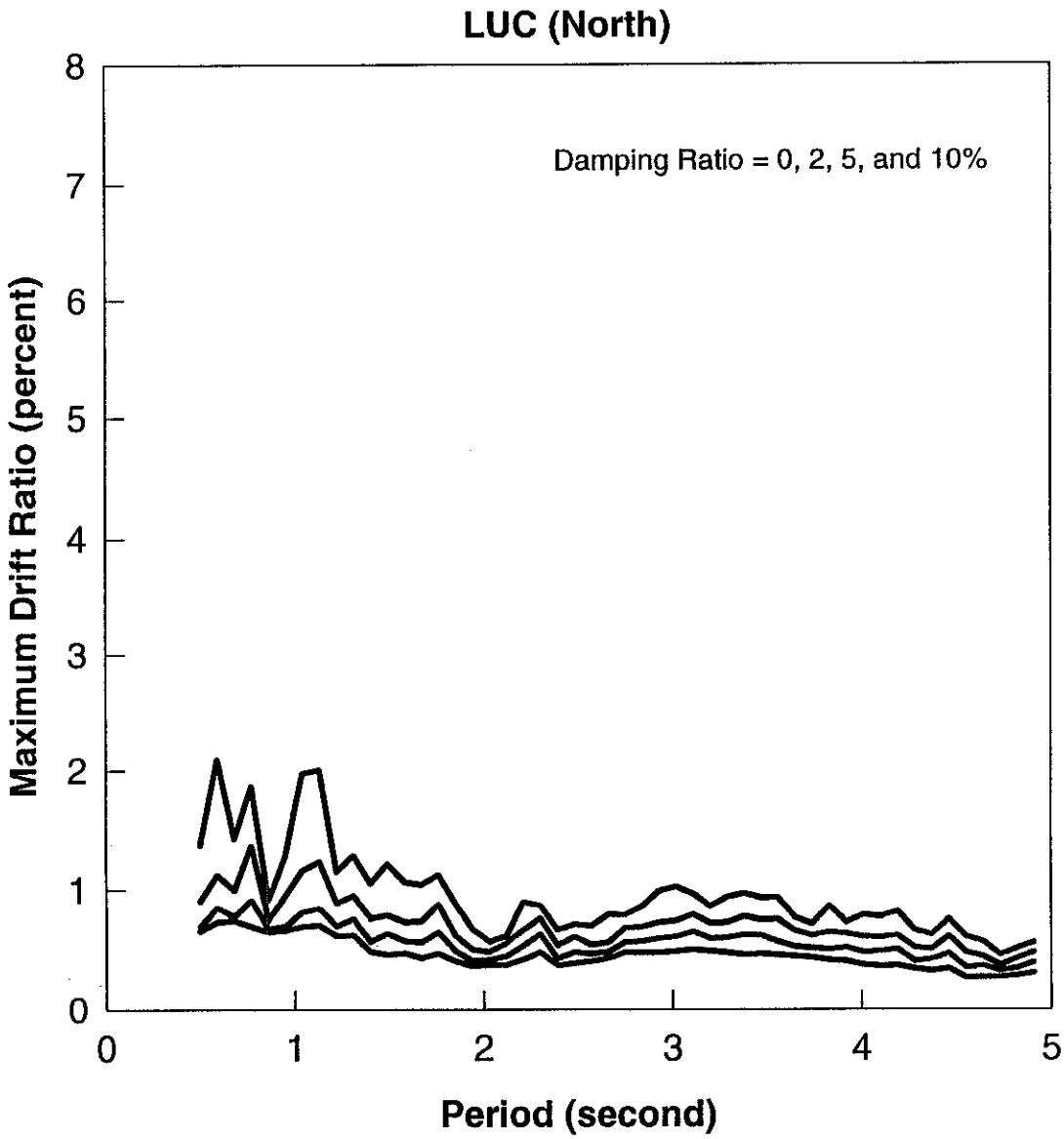

LUC (N80W)
Acceleration (cm/s/s)
Max = −718 cm/s/s
1000
500
0
−500
−1000
0
5
10
15
20
25
30
Velocity (cm/s)
Max = 147 cm/s
150
100
50
0
−50
−100
Displacemnt (cm)
Max = 265 cm
300
200
100
0
−100
Time (second)

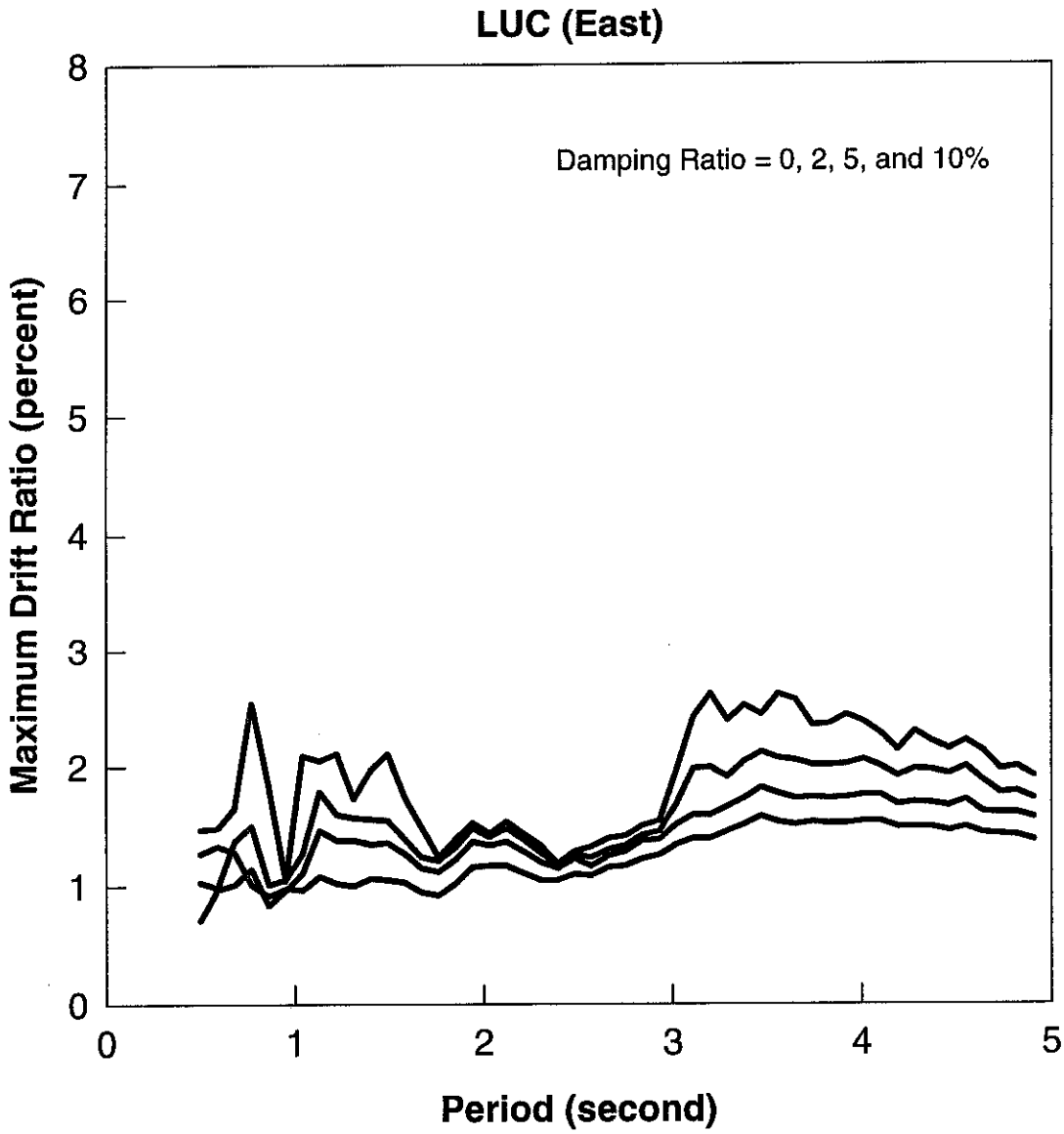

LUC Particle Trajectory
200
150
100
50
0
−50
−100
North (cm)
−250
−200
−150
−100
−50
0
East (cm)

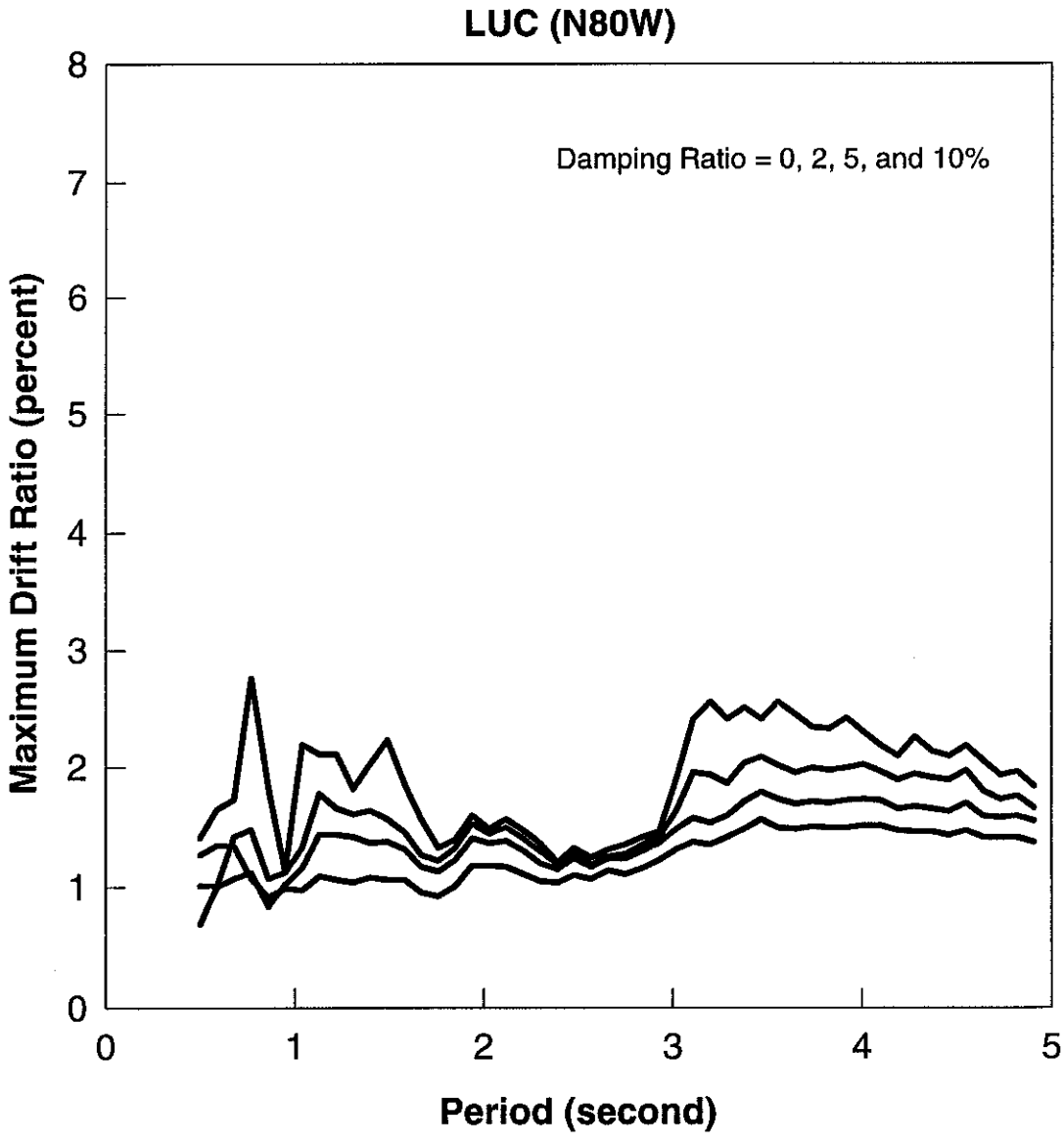

LUC (North)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %


LUC (East)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %

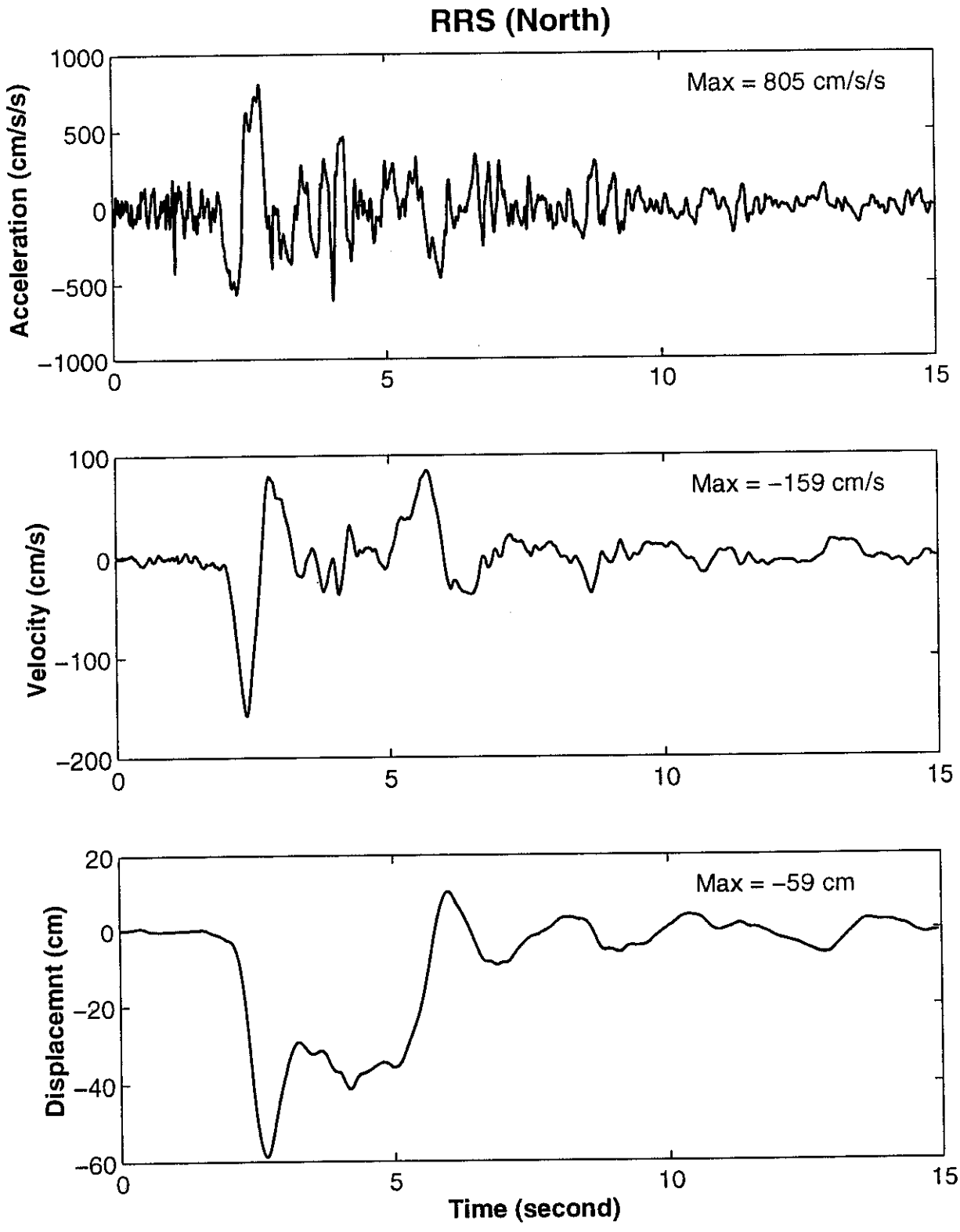

LUC (N80W)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %

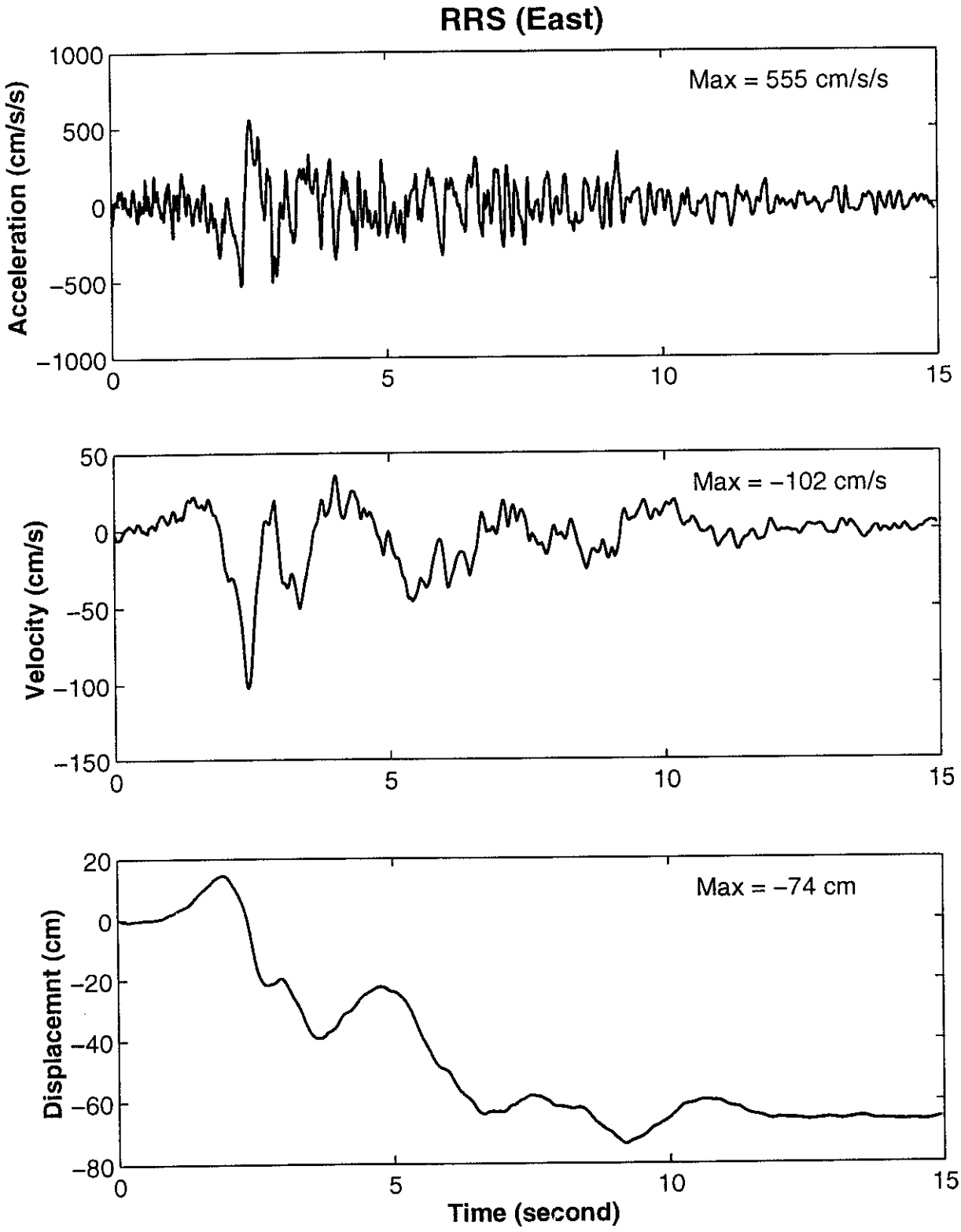

LUC (North)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5

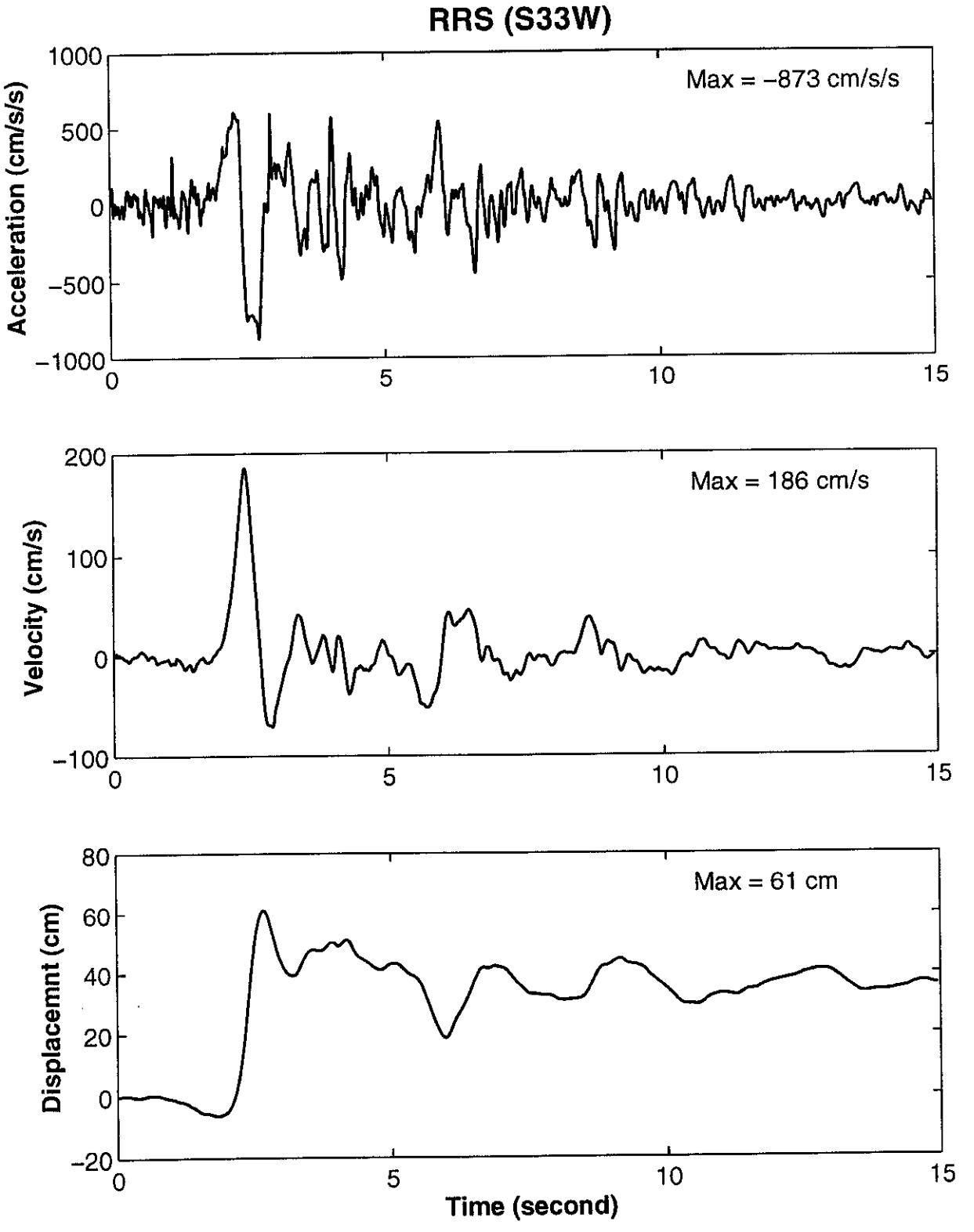

LUC (East)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5

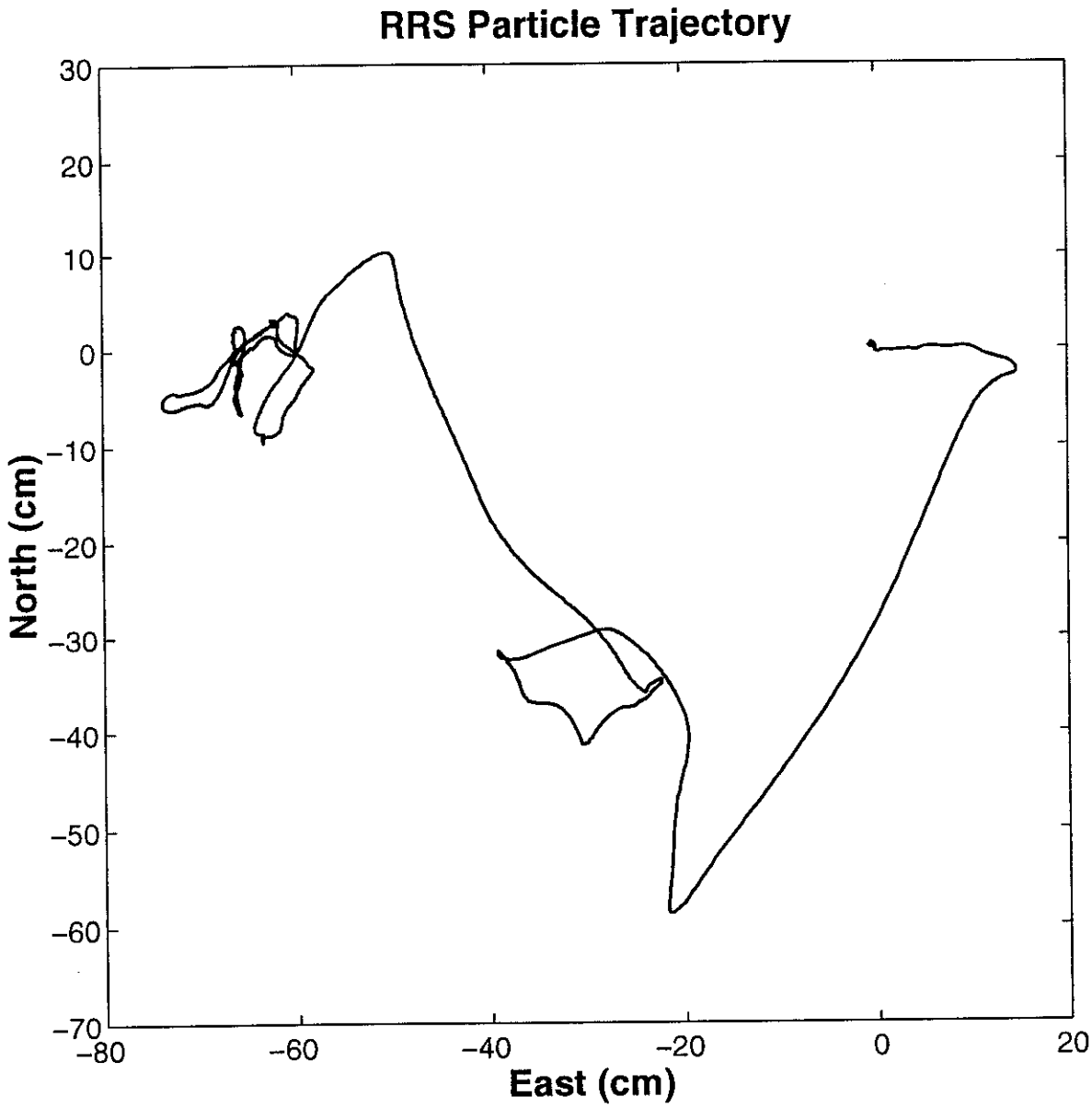

LUC (N80W)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5

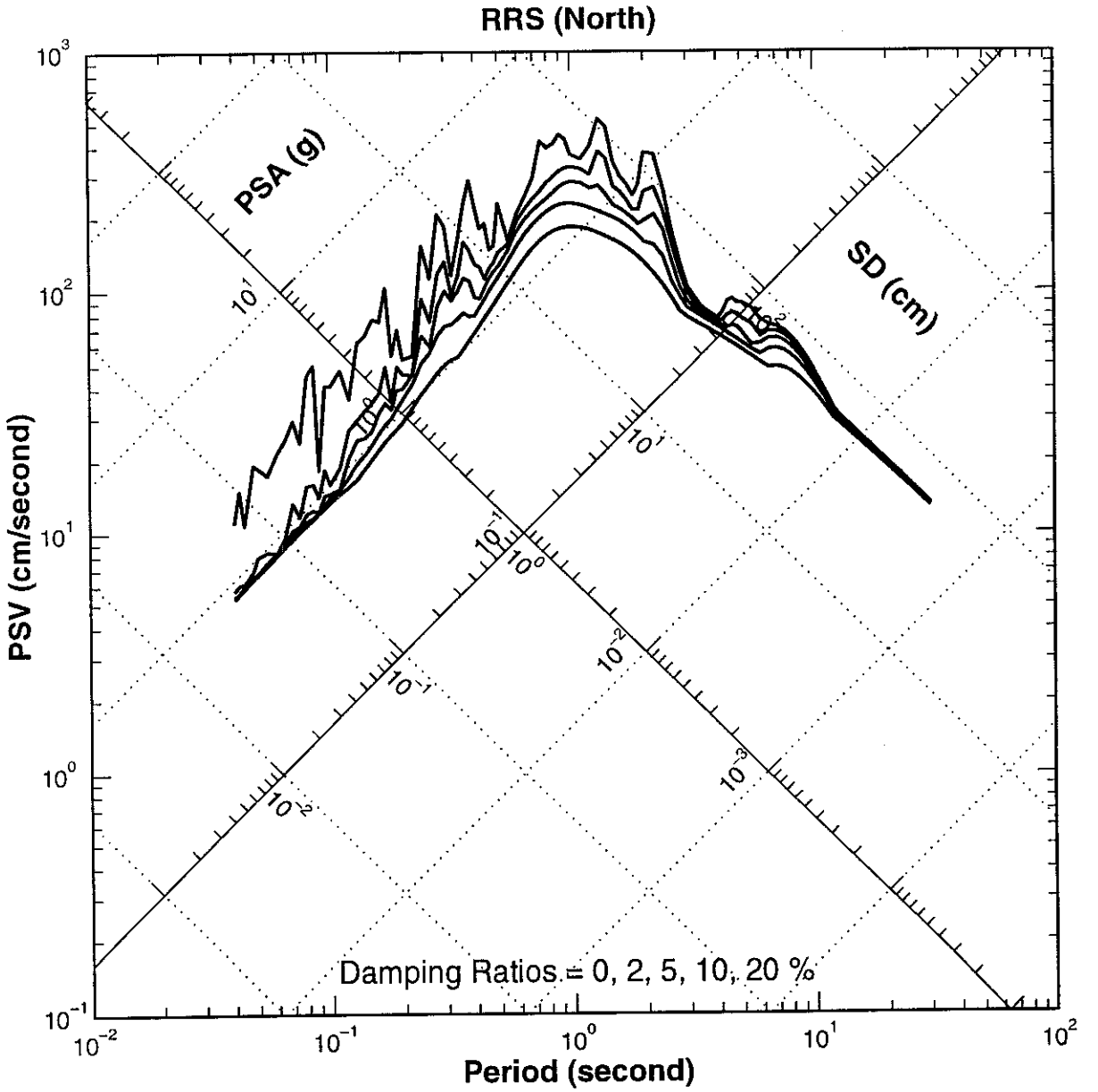
RINALDI RECEIVING STATION (RRS)

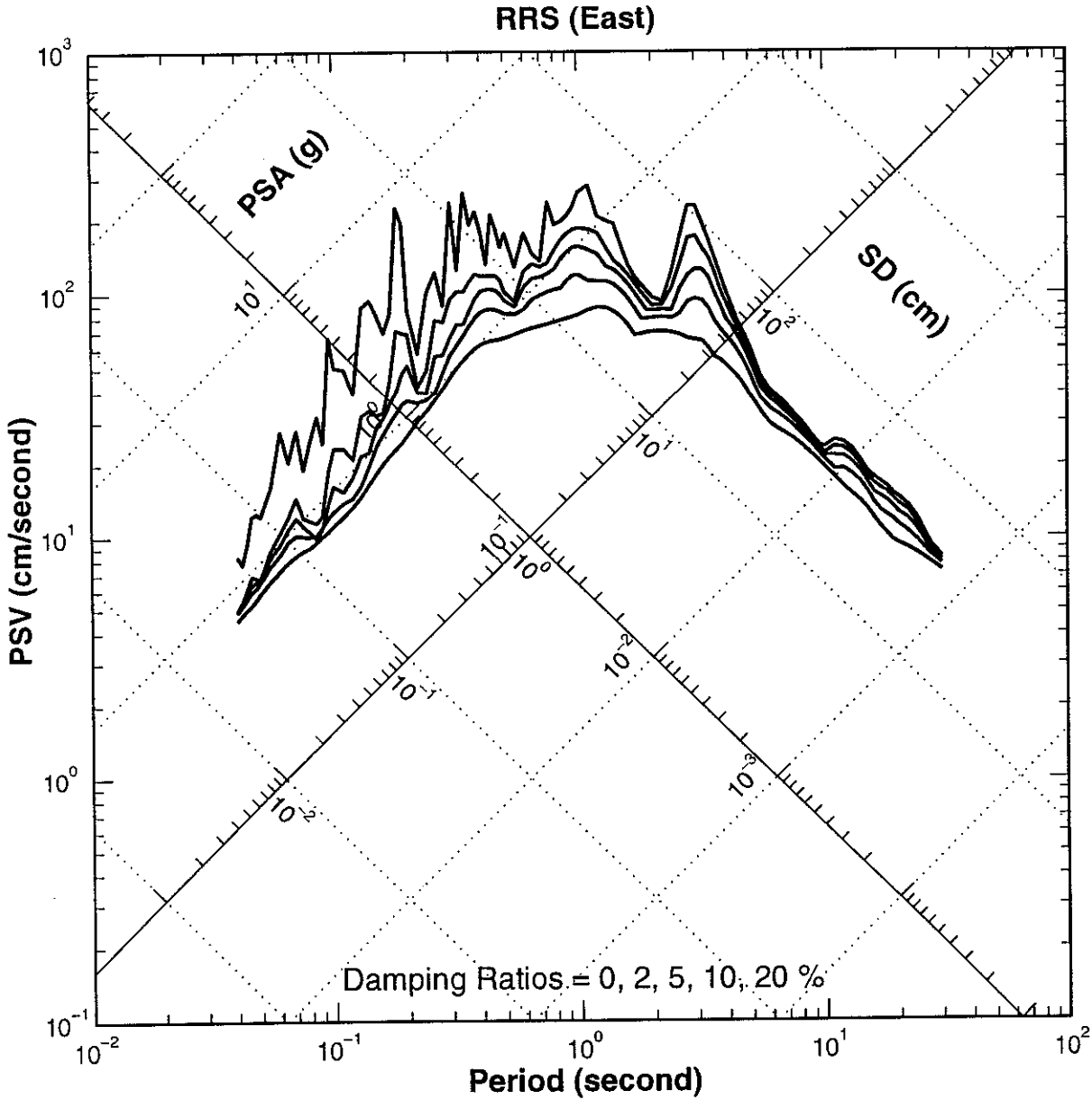

RRS (North)
Acceleration (cm/s/s)
1000
500
0
−500
−1000
Max = 805 cm/s/s
0
5
10
15
Velocity (cm/s)
100
0
−100
−200
Max = −159 cm/s
0
5
10
15
Displacemnt (cm)
20
0
−20
−40
−60
Max = −59 cm
0
5
10
15
Time (second)

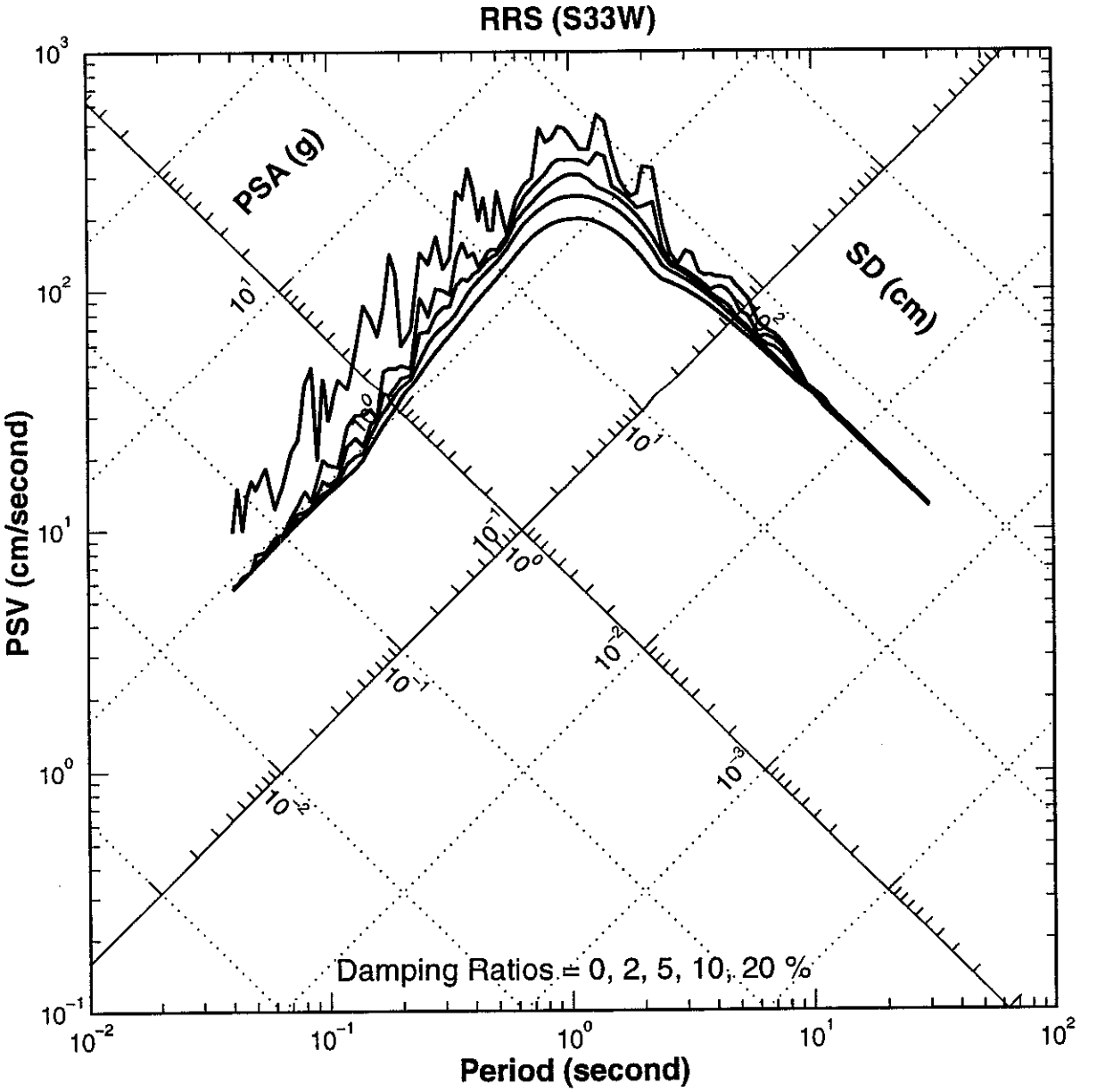

RRS (East)
Max = 555 cm/s/s
Acceleration (cm/s/s)
1000
500
0
−500
−1000
0
5
10
15
Max = −102 cm/s
Velocity (cm/s)
50
0
−50
−100
−150
0
5
10
15
Max = −74 cm
Displacemnt (cm)
20
0
−20
−40
−60
−80
0
5
10
15
Time (second)

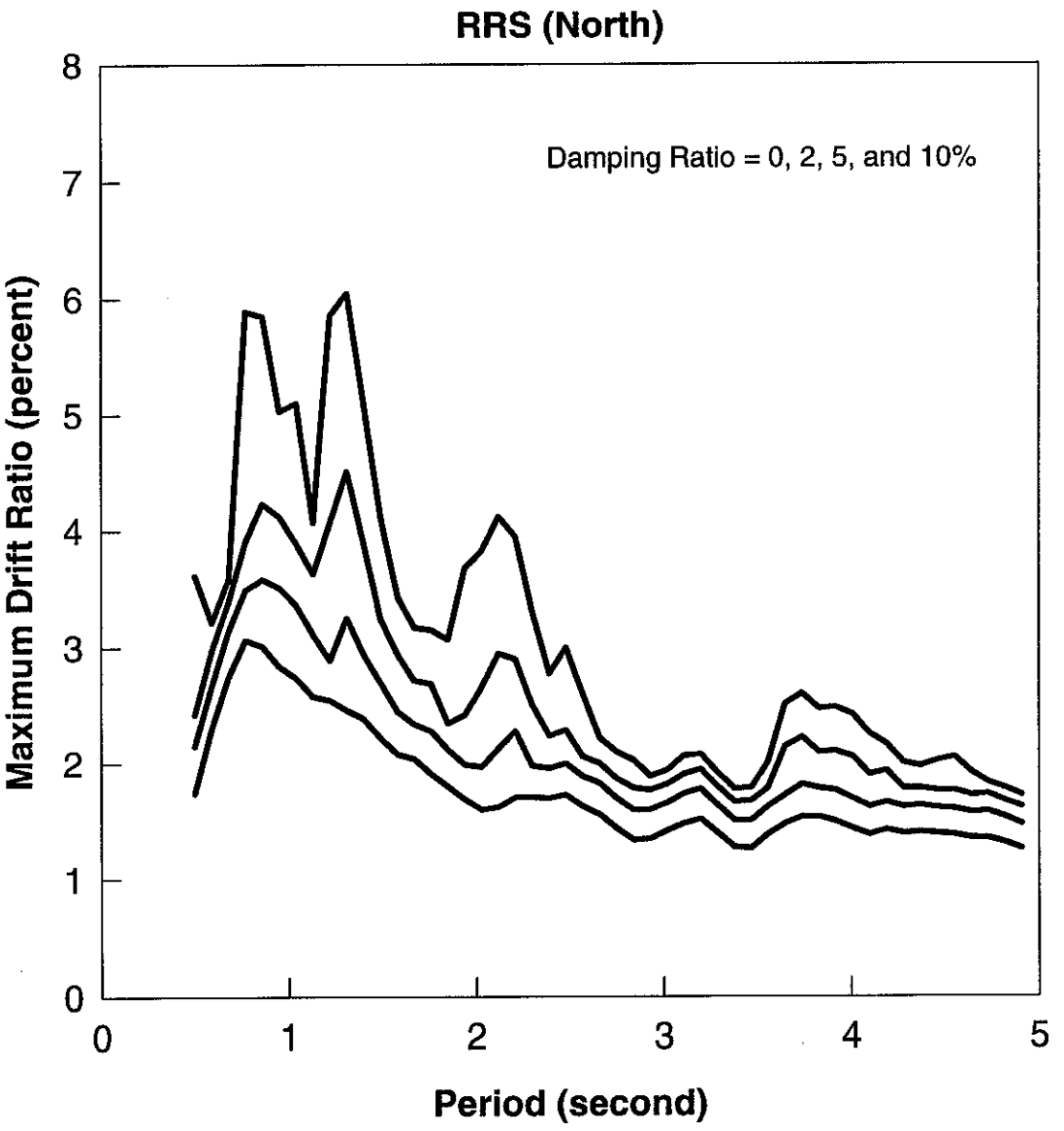

RRS (S33W)
Max = −873 cm/s/s
Acceleration (cm/s/s)
1000
500
0
−500
−1000
0
5
10
15
Max = 186 cm/s
Velocity (cm/s)
200
100
0
−100
0
5
10
15
Max = 61 cm
Displacemnt (cm)
80
60
40
20
0
−20
0
5
10
15
Time (second)

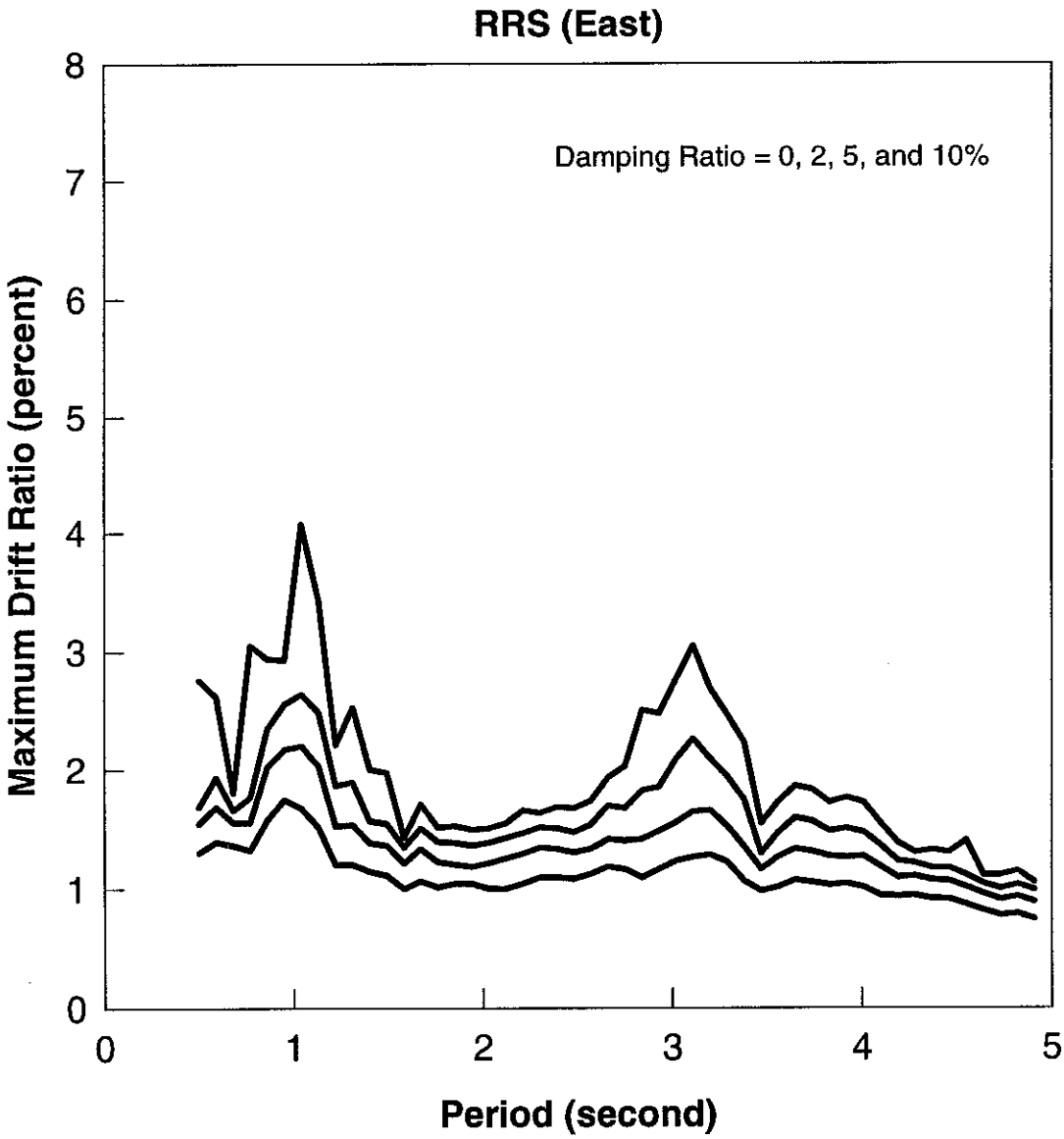

RRS Particle Trajectory
North (cm)
East (cm)
30
20
10
0
−10
−20
−30
−40
−50
−60
−70
−80
−60
−40
−20
0
20

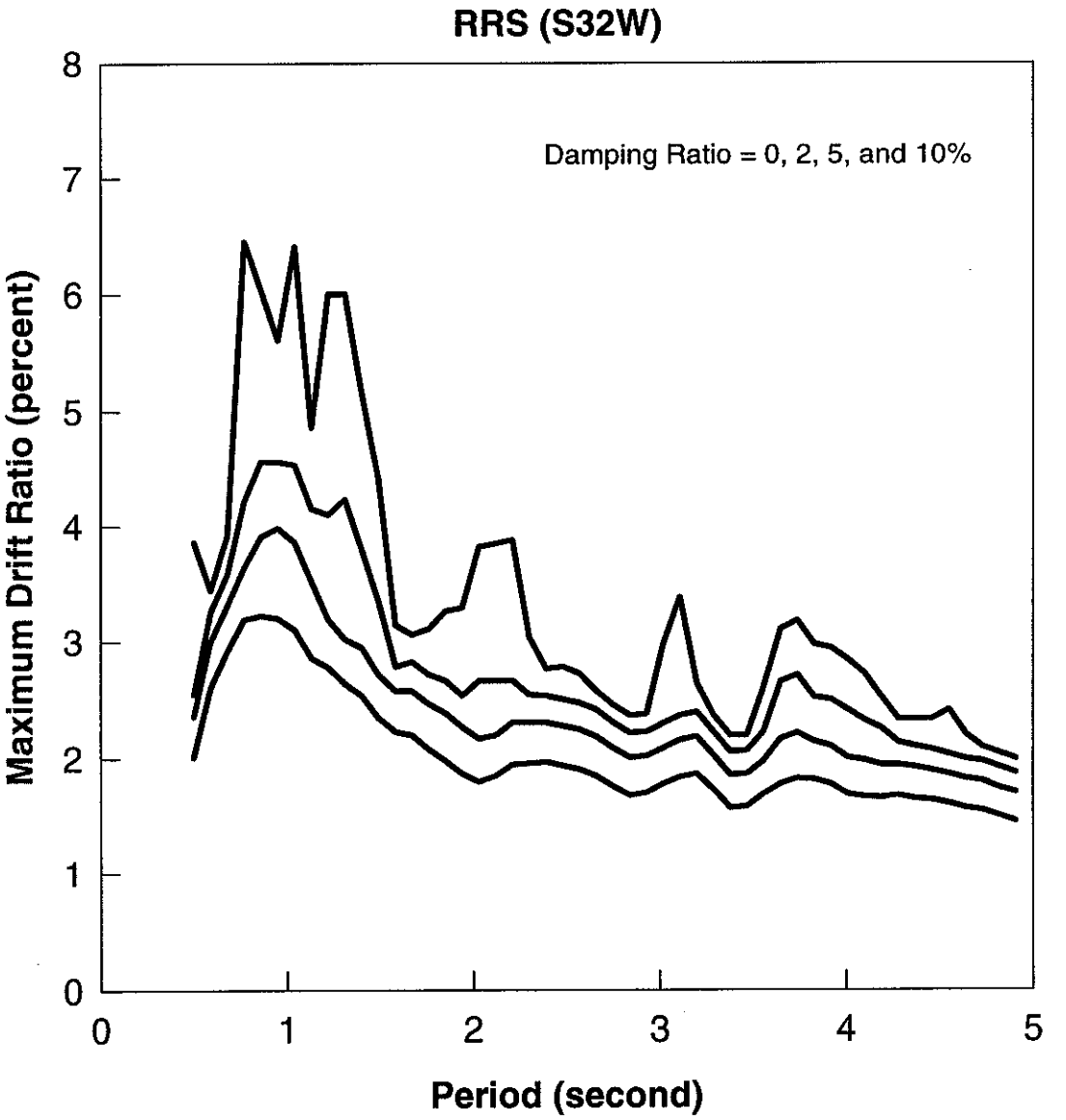

RRS (North)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %


RRS (East)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %

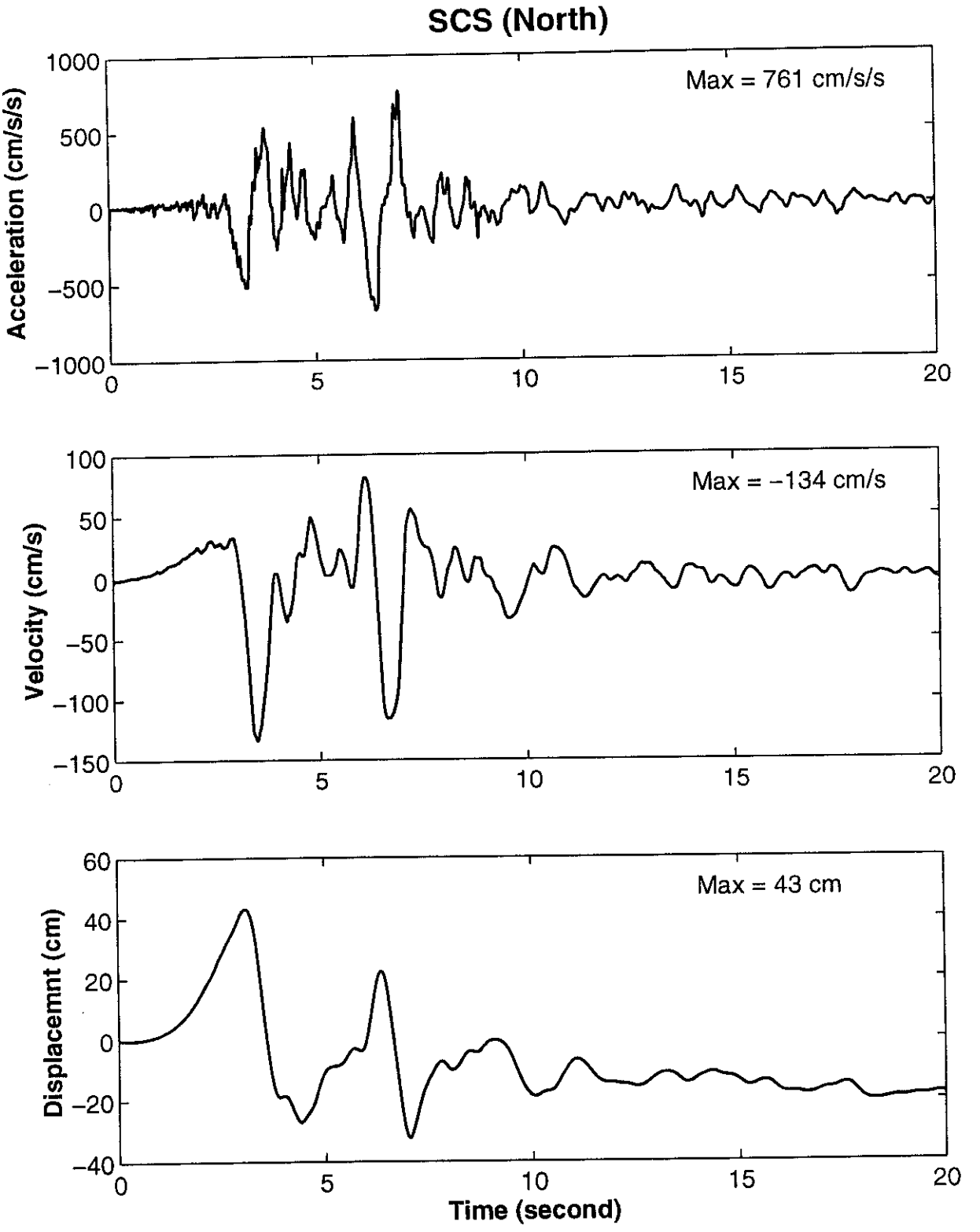

RRS (S33W)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %

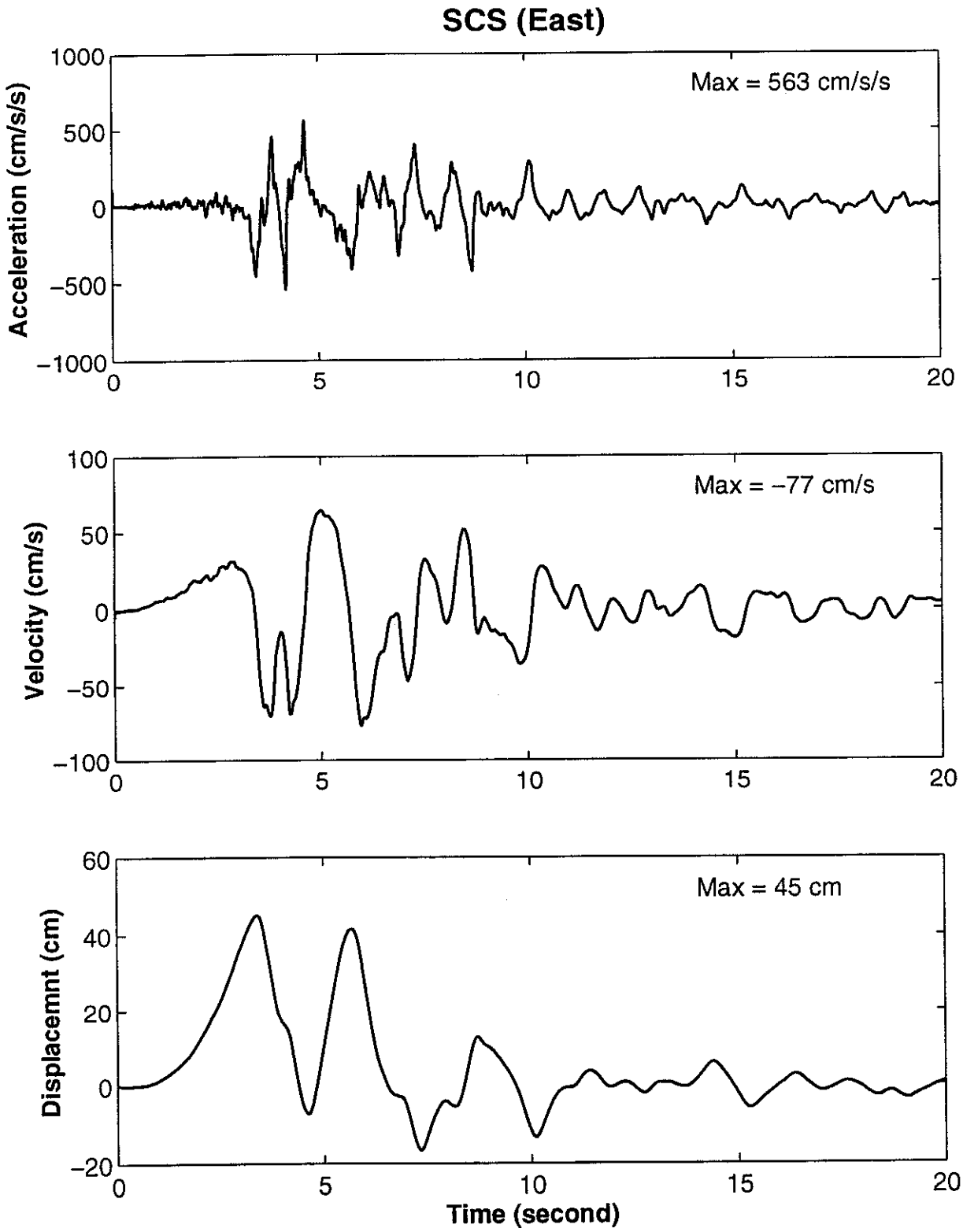

RRS (North)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5

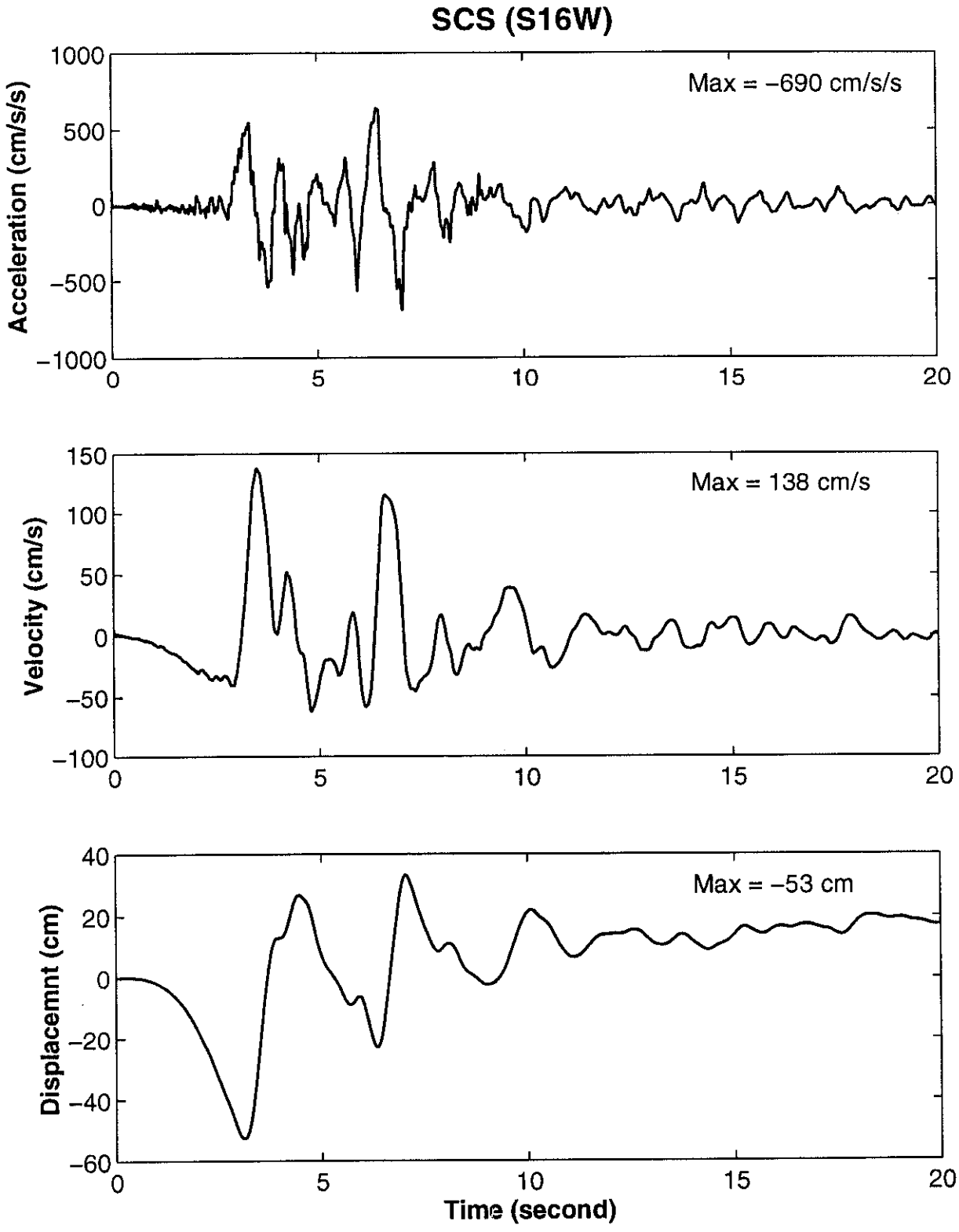

RRS (East)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5

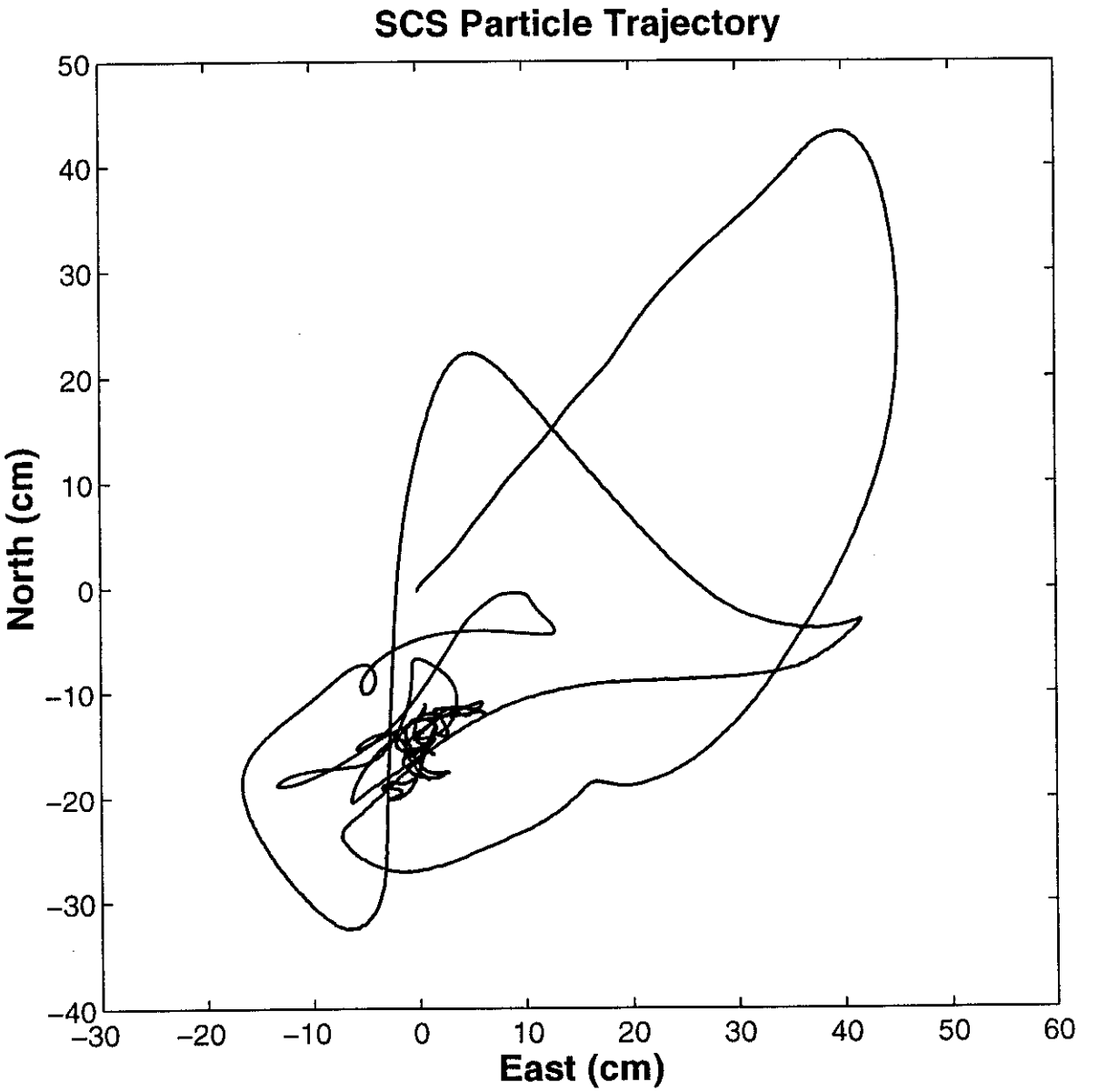

RRS (S32W)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5

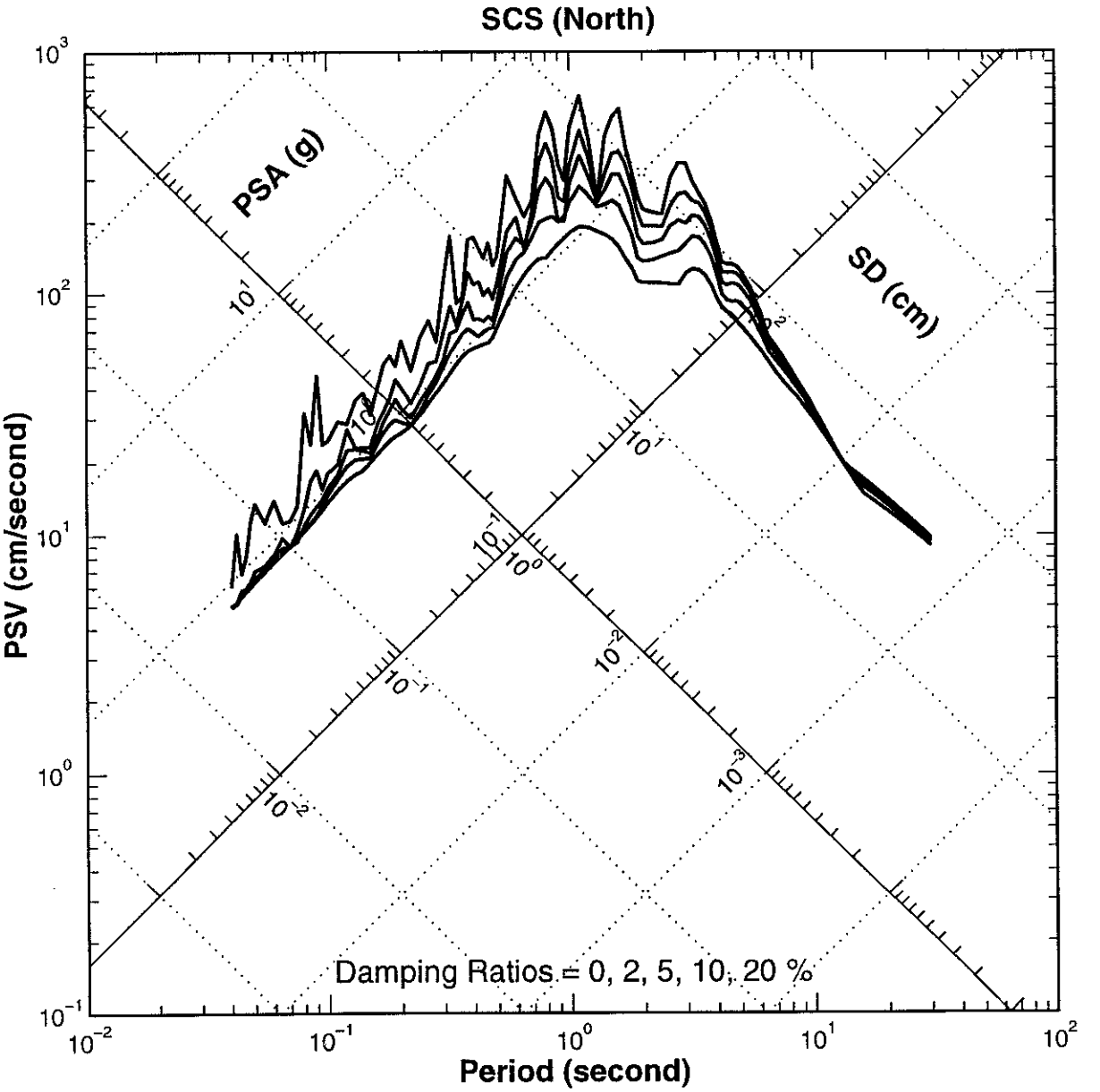
SYLMAR CONVERTER STATION (SCS)

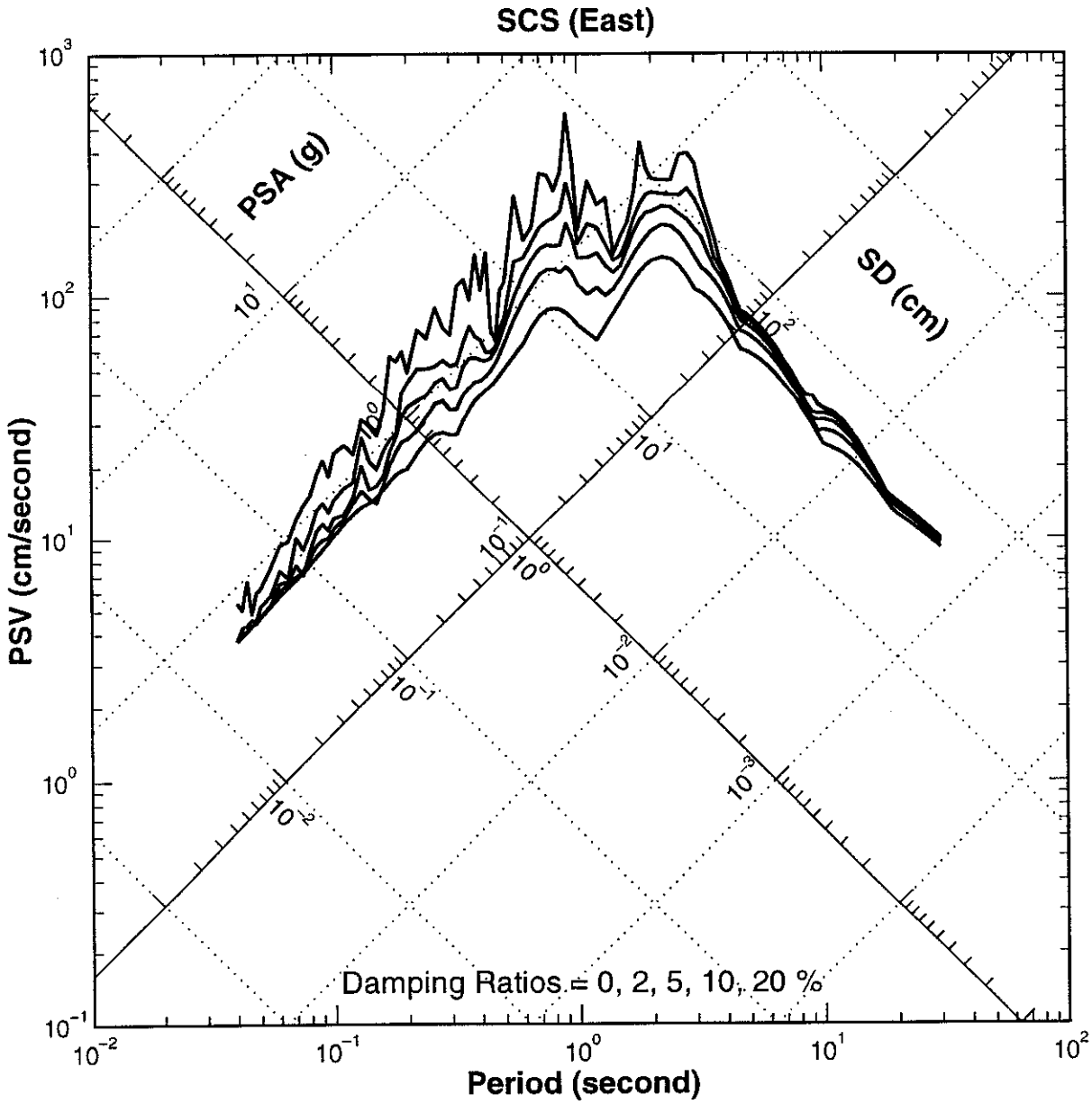

SCS (North)
Max = 761 cm/s/s
Acceleration (cm/s/s)
1000
500
0
−500
−1000
0
5
10
15
20
Max = −134 cm/s
Velocity (cm/s)
100
50
0
−50
−100
−150
Max = 43 cm
Displacemnt (cm)
60
40
20
0
−20
−40
Time (second)

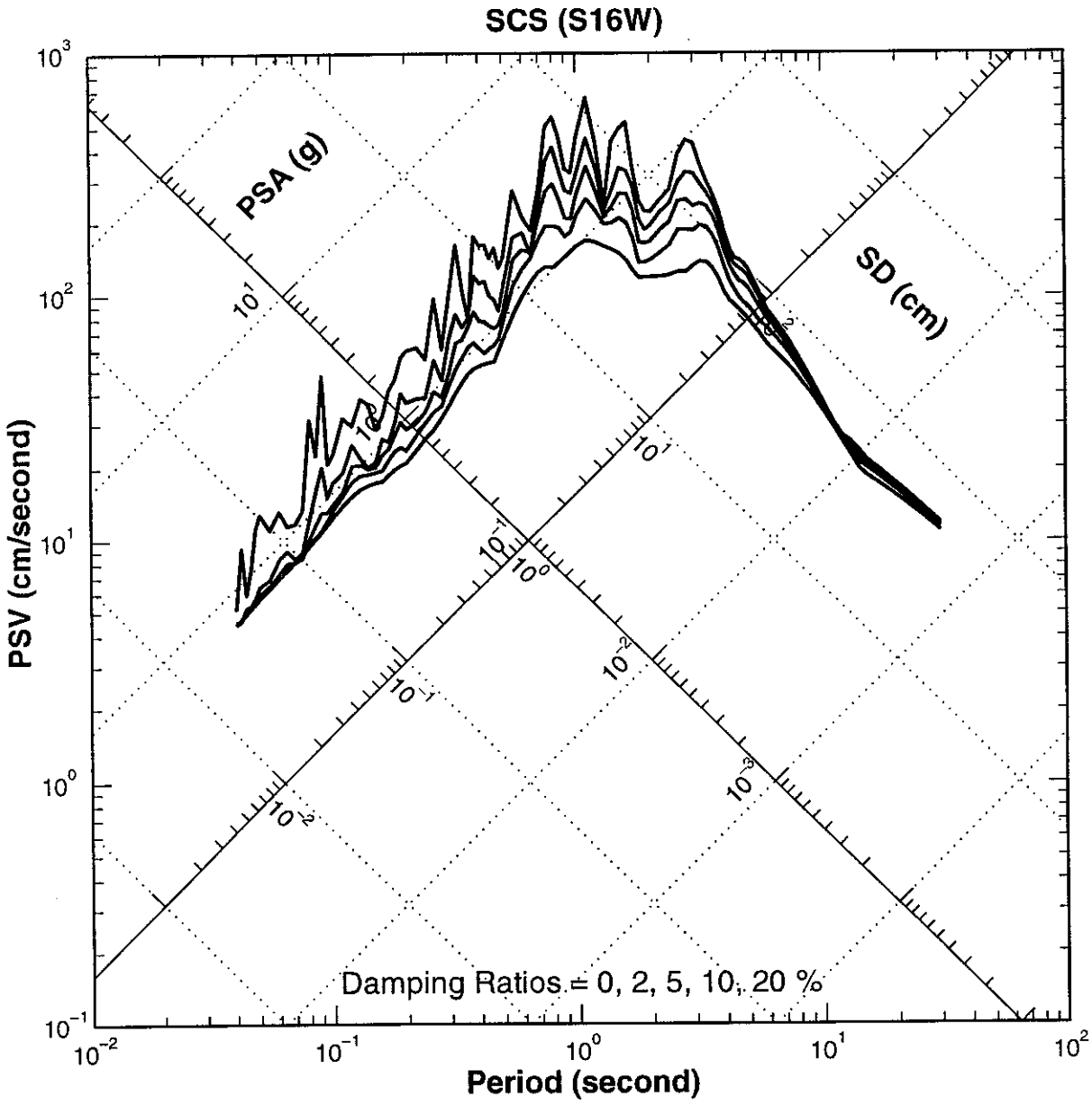

SCS (East)
Max = 563 cm/s/s
Acceleration (cm/s/s)
1000
500
0
−500
−1000
0
5
10
15
20
Max = −77 cm/s
Velocity (cm/s)
100
50
0
−50
−100
Max = 45 cm
Displacemnt (cm)
60
40
20
0
−20
Time (second)

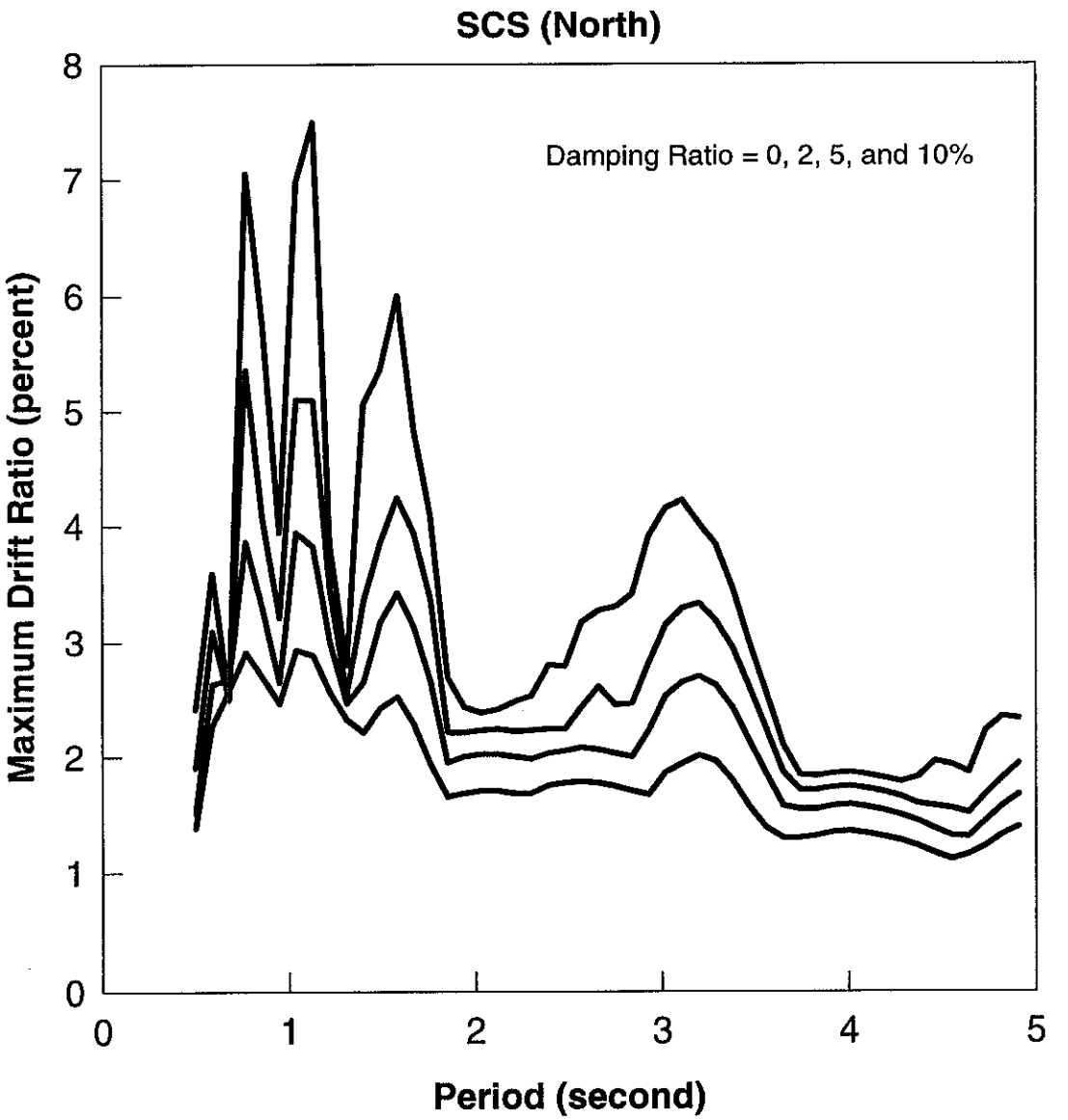

SCS (S16W)
Acceleration (cm/s/s)
Max = −690 cm/s/s
1000
500
0
−500
−1000
0
5
10
15
20
Velocity (cm/s)
Max = 138 cm/s
150
100
50
0
−50
−100
Displacemnt (cm)
Max = −53 cm
40
20
0
−20
−40
−60
Time (second)

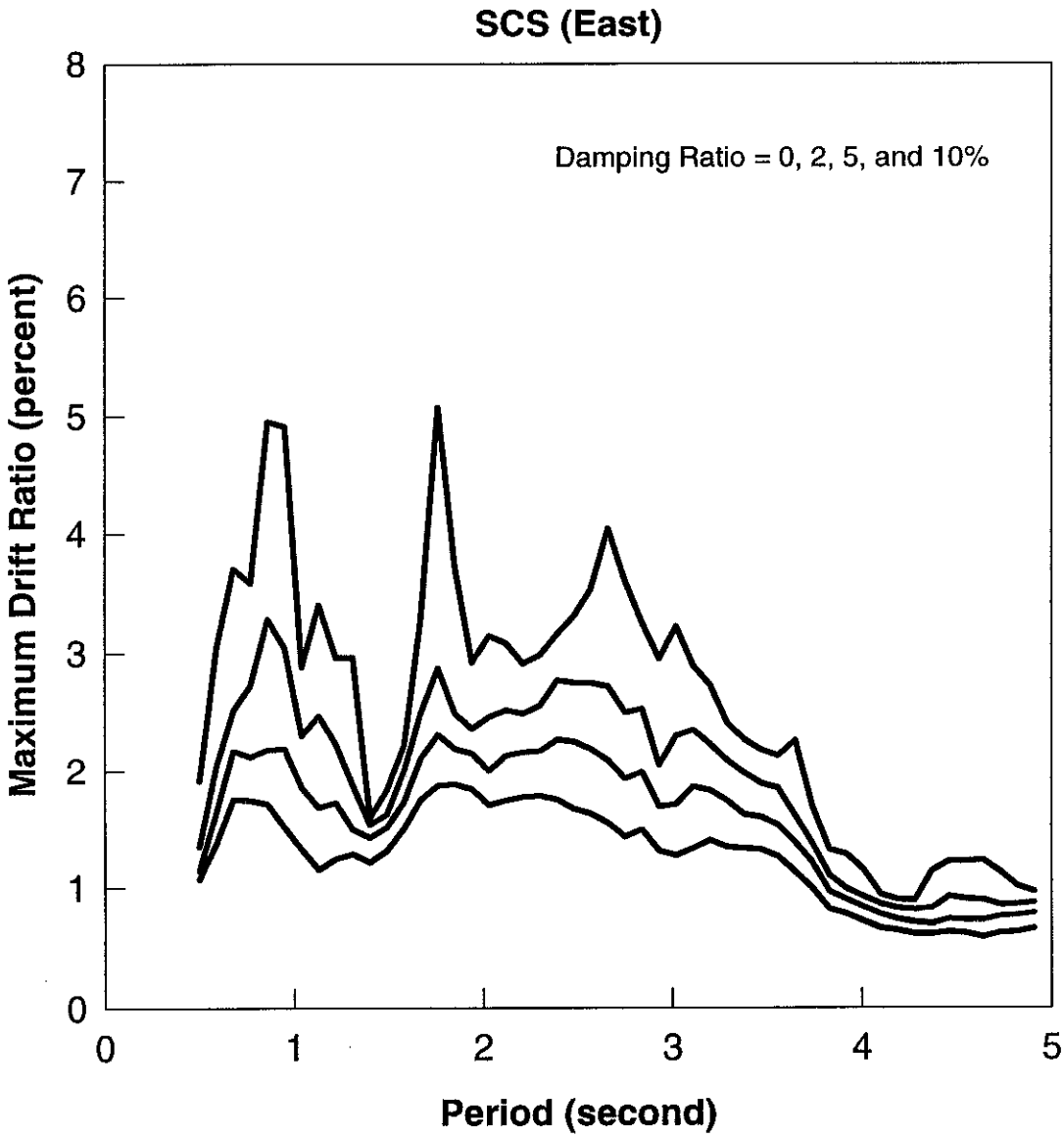

SCS Particle Trajectory
North (cm)
East (cm)
50
40
30
20
10
0
−10
−20
−30
−40
−30
−20
−10
0
10
20
30
40
50
60

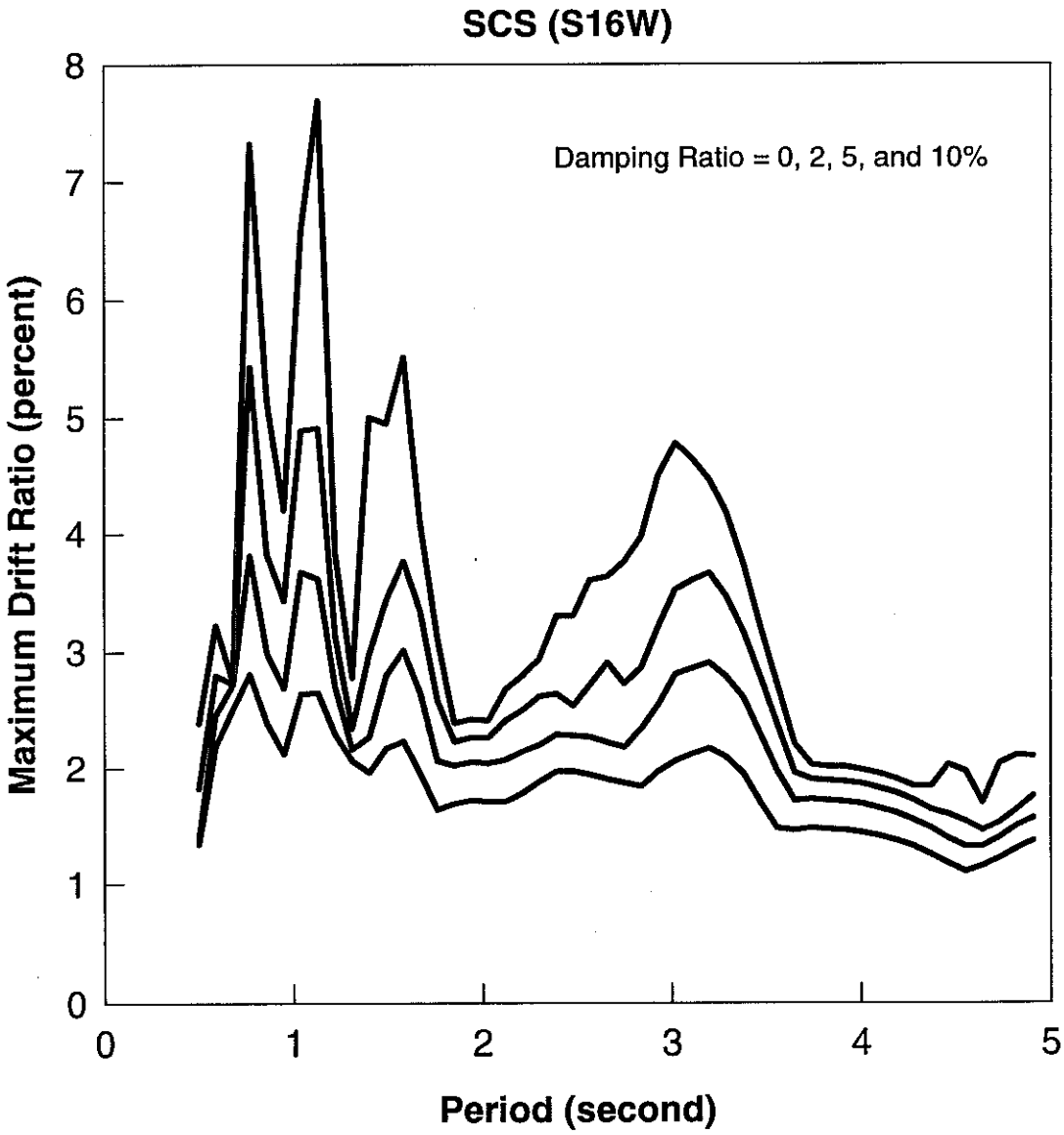

SCS (North)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %


SCS (East)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %

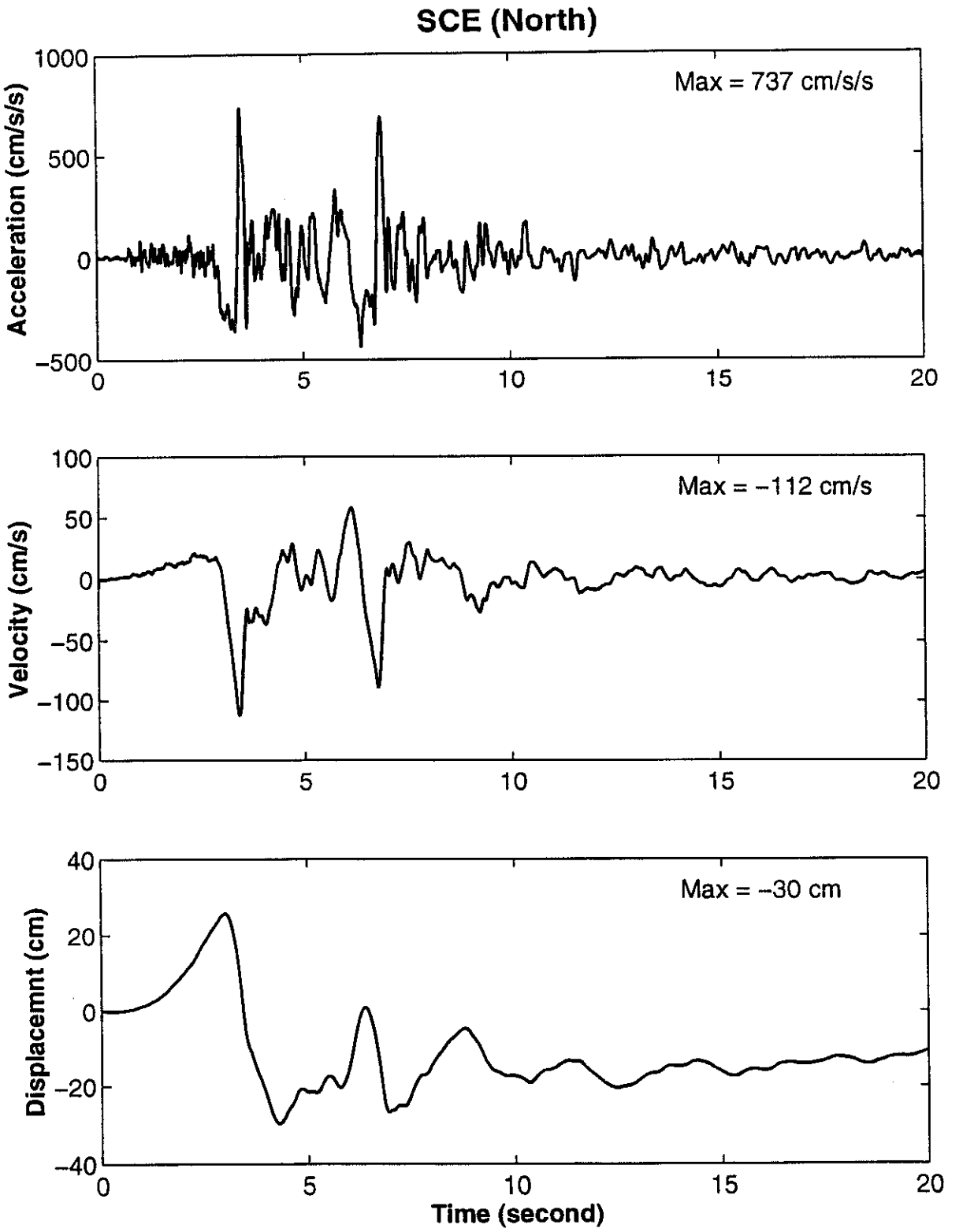

SCS (S16W)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %

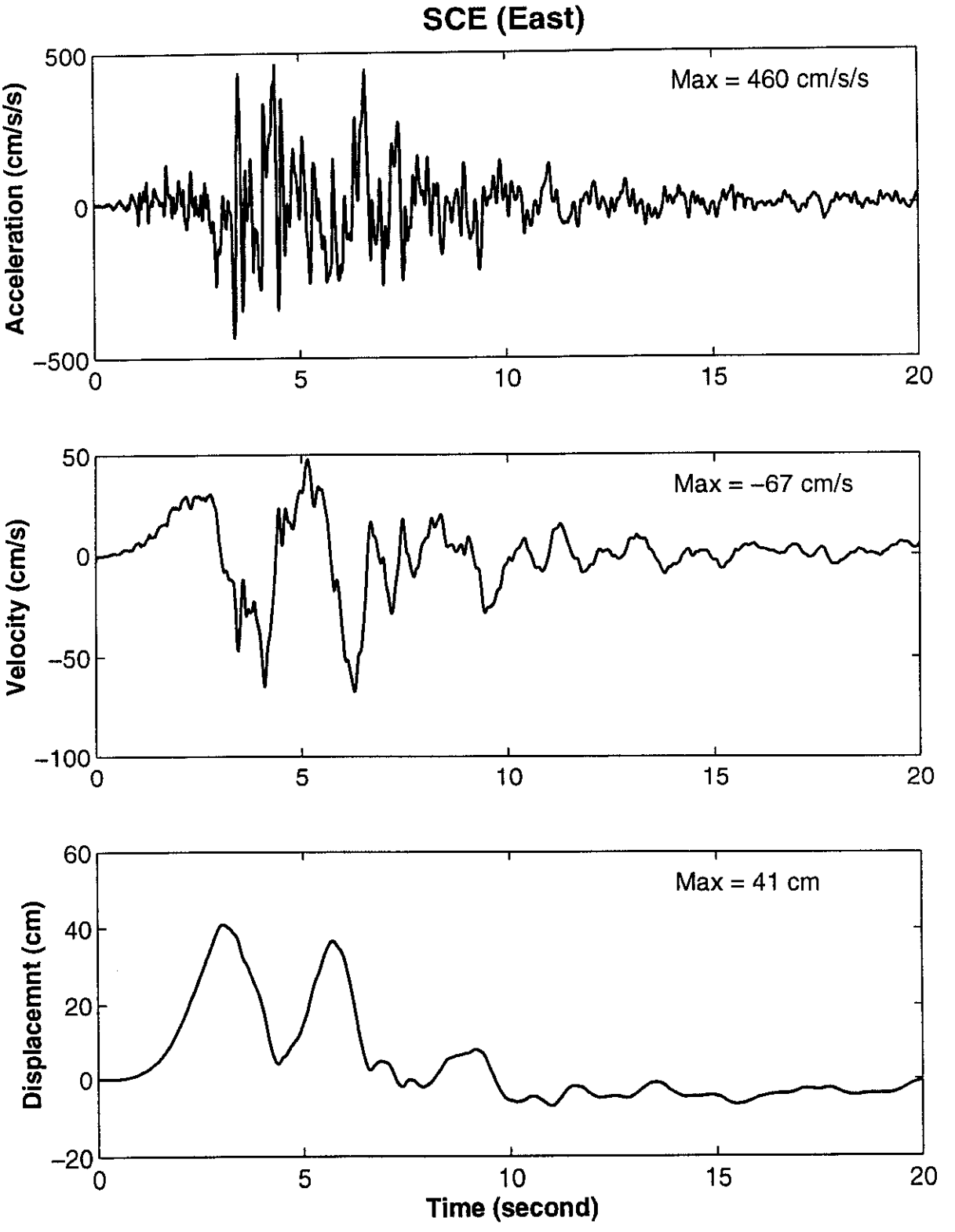

SCS (North)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5

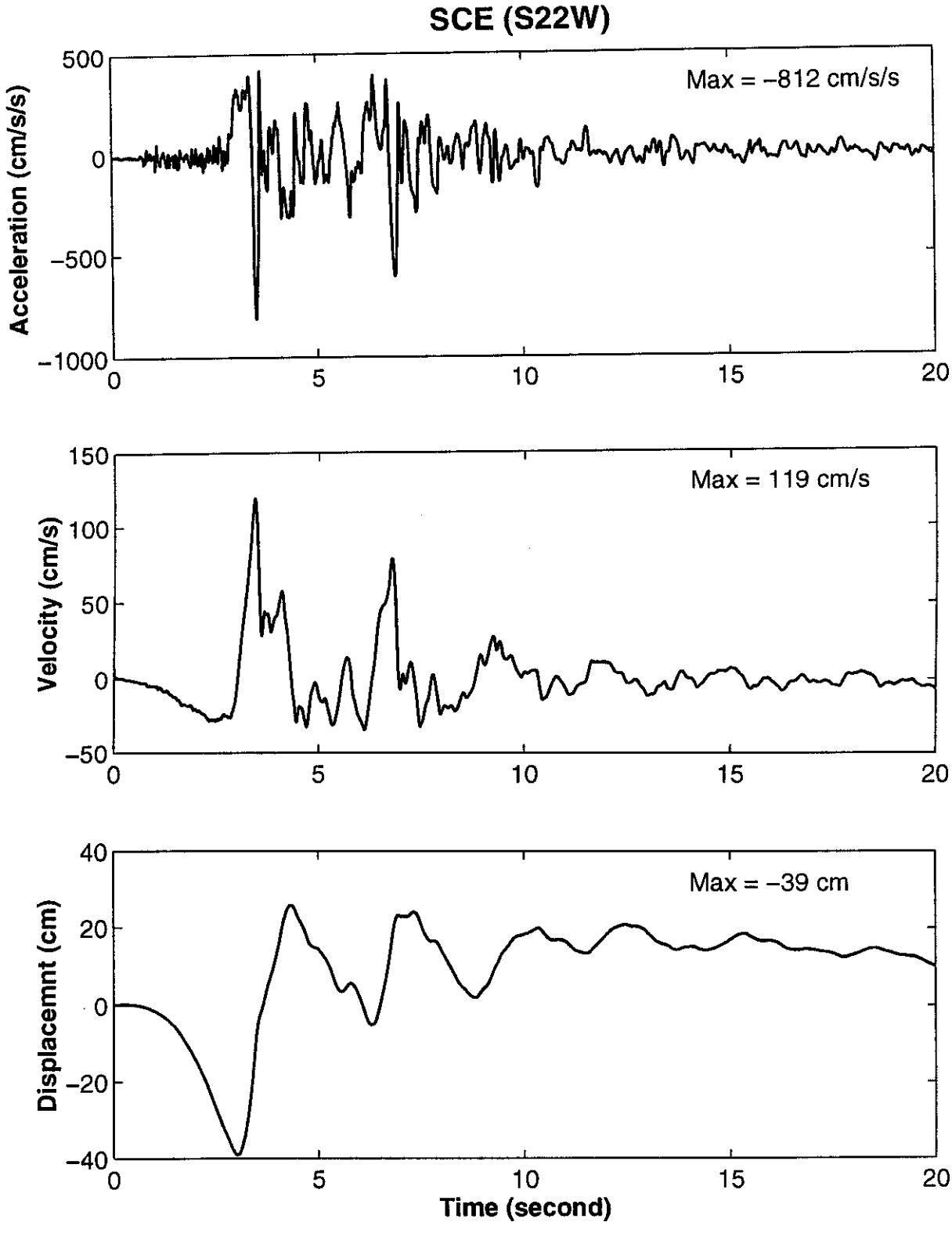

SCS (East)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5

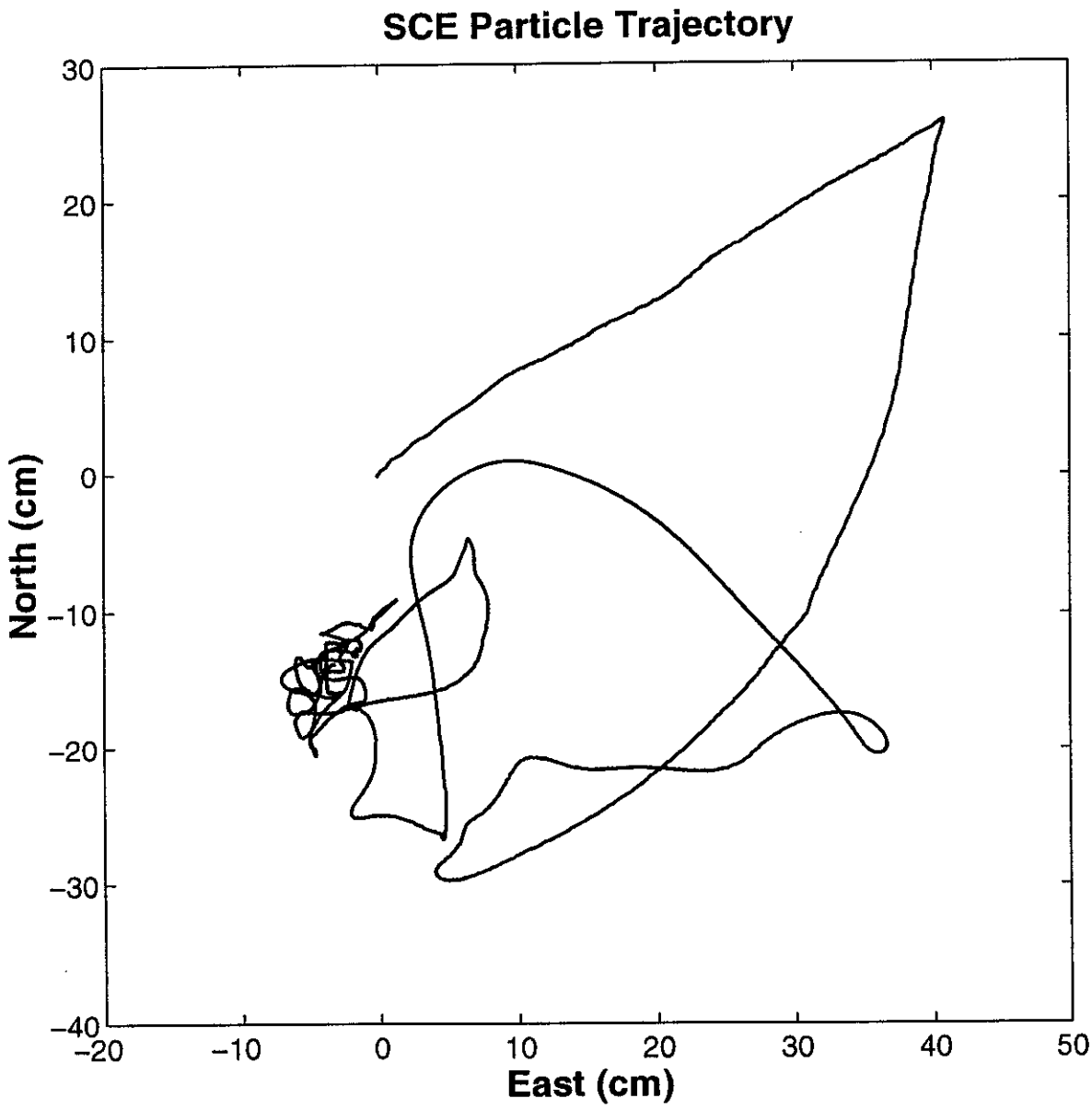

SCS (S16W)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5

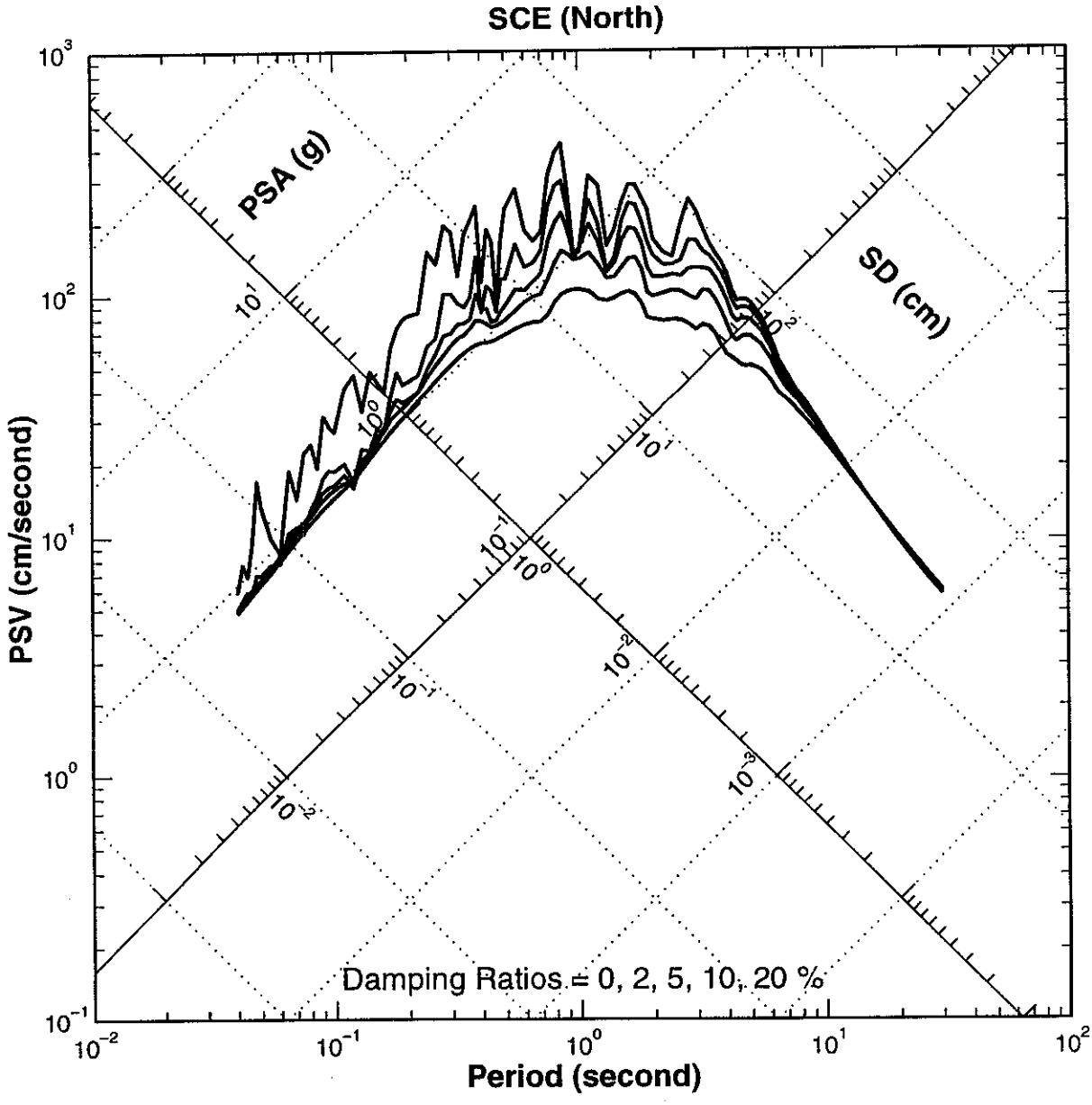
SYLMAR CONVERTER STATION - EAST (SCE)

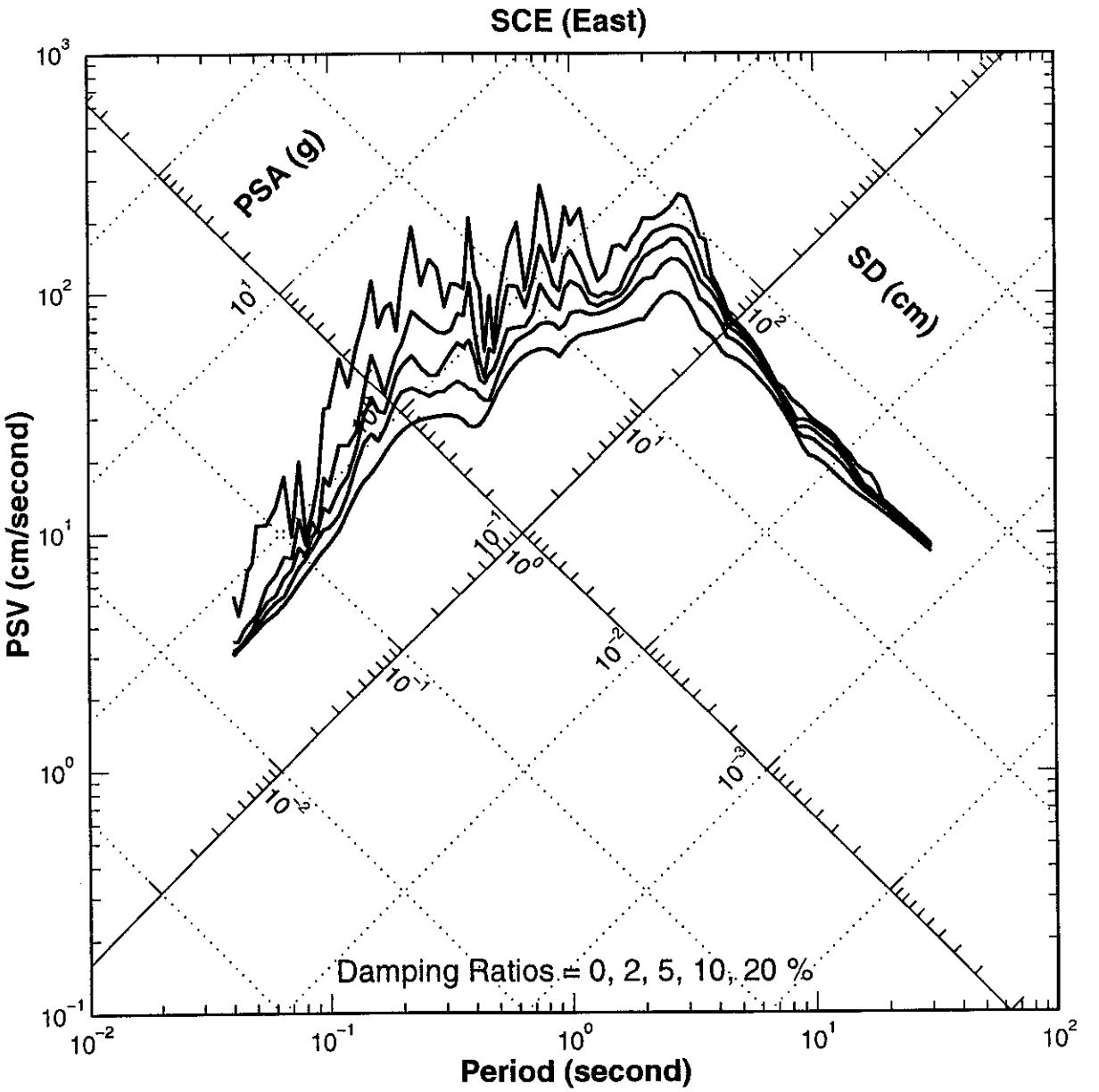

SCE (North)
Max = 737 cm/s/s
Acceleration (cm/s/s)
1000
500
0
−500
0
5
10
15
20
Max = −112 cm/s
Velocity (cm/s)
100
50
0
−50
−100
−150
Max = −30 cm
Displacemnt (cm)
40
20
0
−20
−40
Time (second)

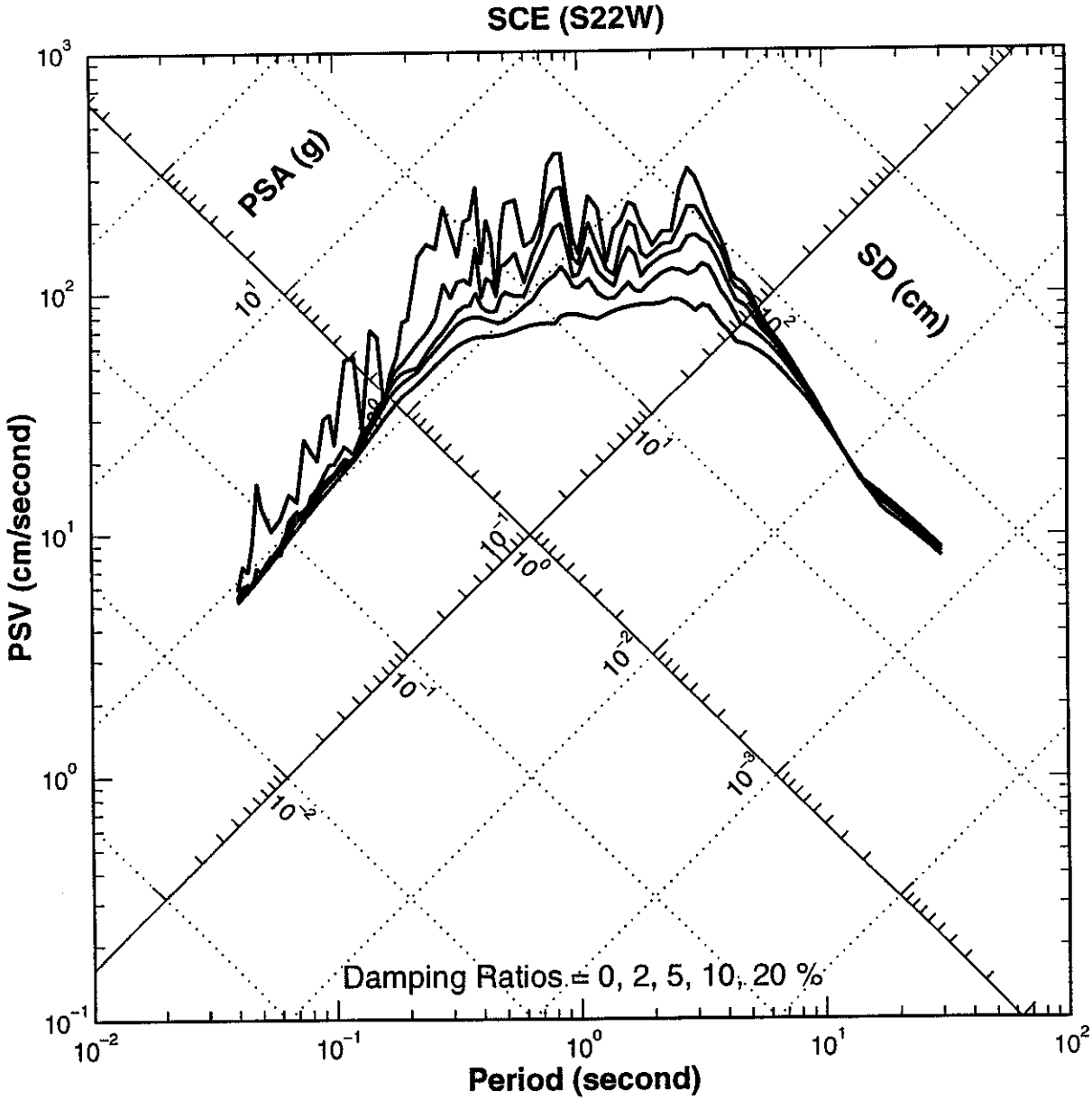

SCE (East)
Acceleration (cm/s/s)
500
0
−500
Max = 460 cm/s/s
0
5
10
15
20
Velocity (cm/s)
50
0
−50
−100
Max = −67 cm/s
Displacemnt (cm)
60
40
20
0
−20
Max = 41 cm
Time (second)

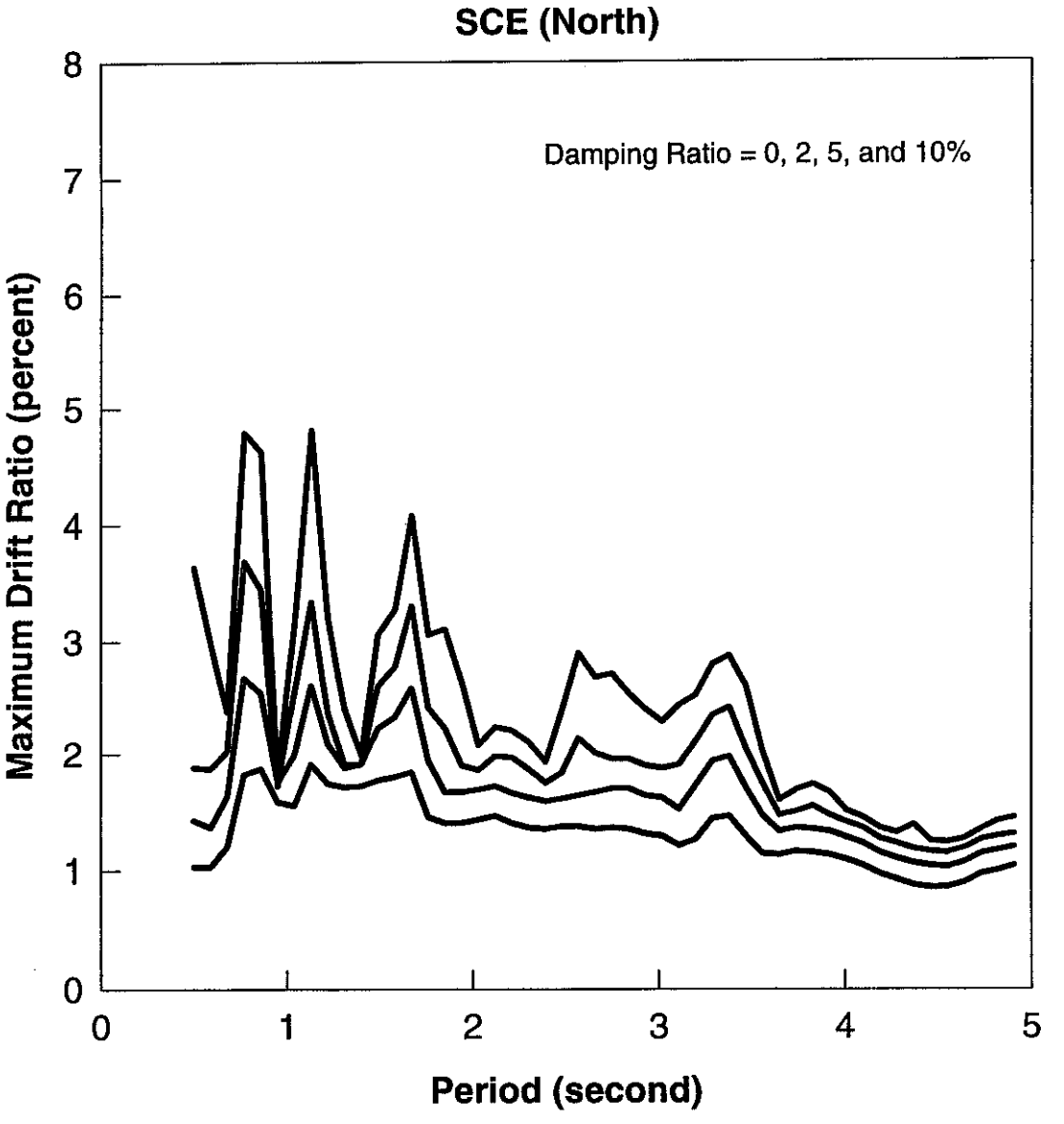

SCE (S22W)
Max = −812 cm/s/s
Acceleration (cm/s/s)
500
0
−500
−1000
0
5
10
15
20
Max = 119 cm/s
Velocity (cm/s)
150
100
50
0
−50
Max = −39 cm
Displacemnt (cm)
40
20
0
−20
−40
Time (second)

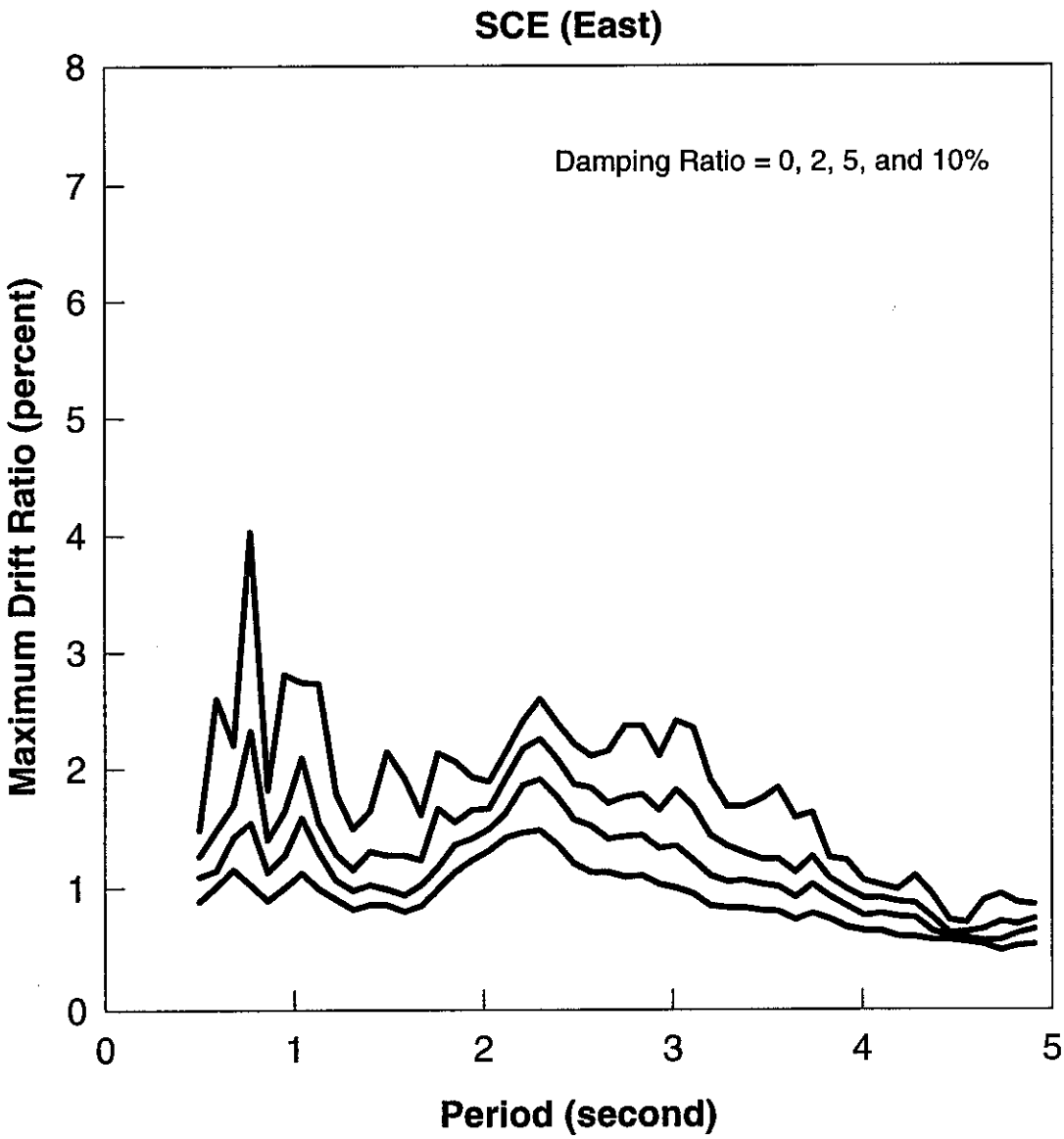

SCE Particle Trajectory
North (cm)
East (cm)
30
20
10
0
−10
−20
−30
−40
−20
−10
0
10
20
30
40
50

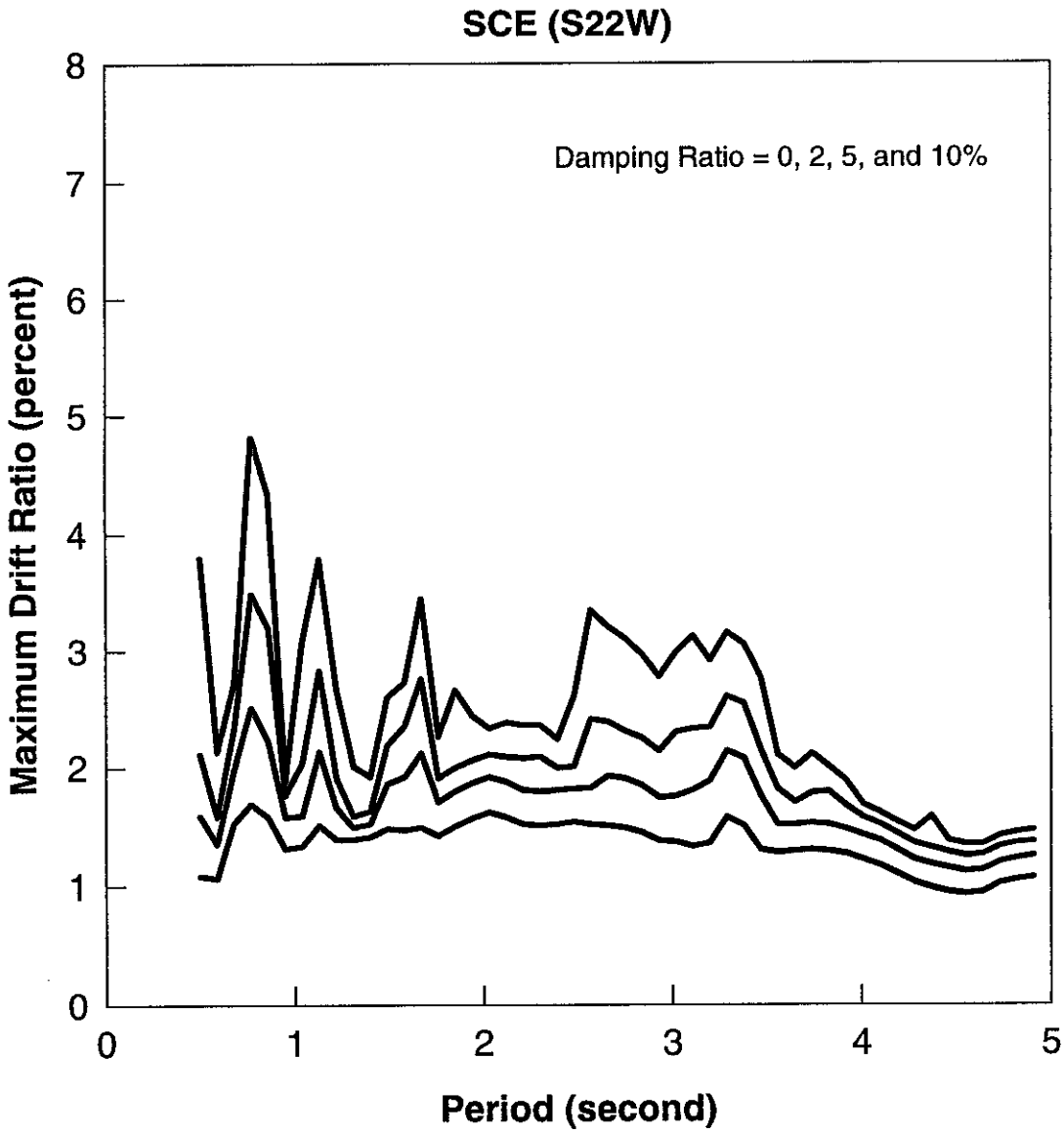

SCE (North)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %


SCE (East)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %

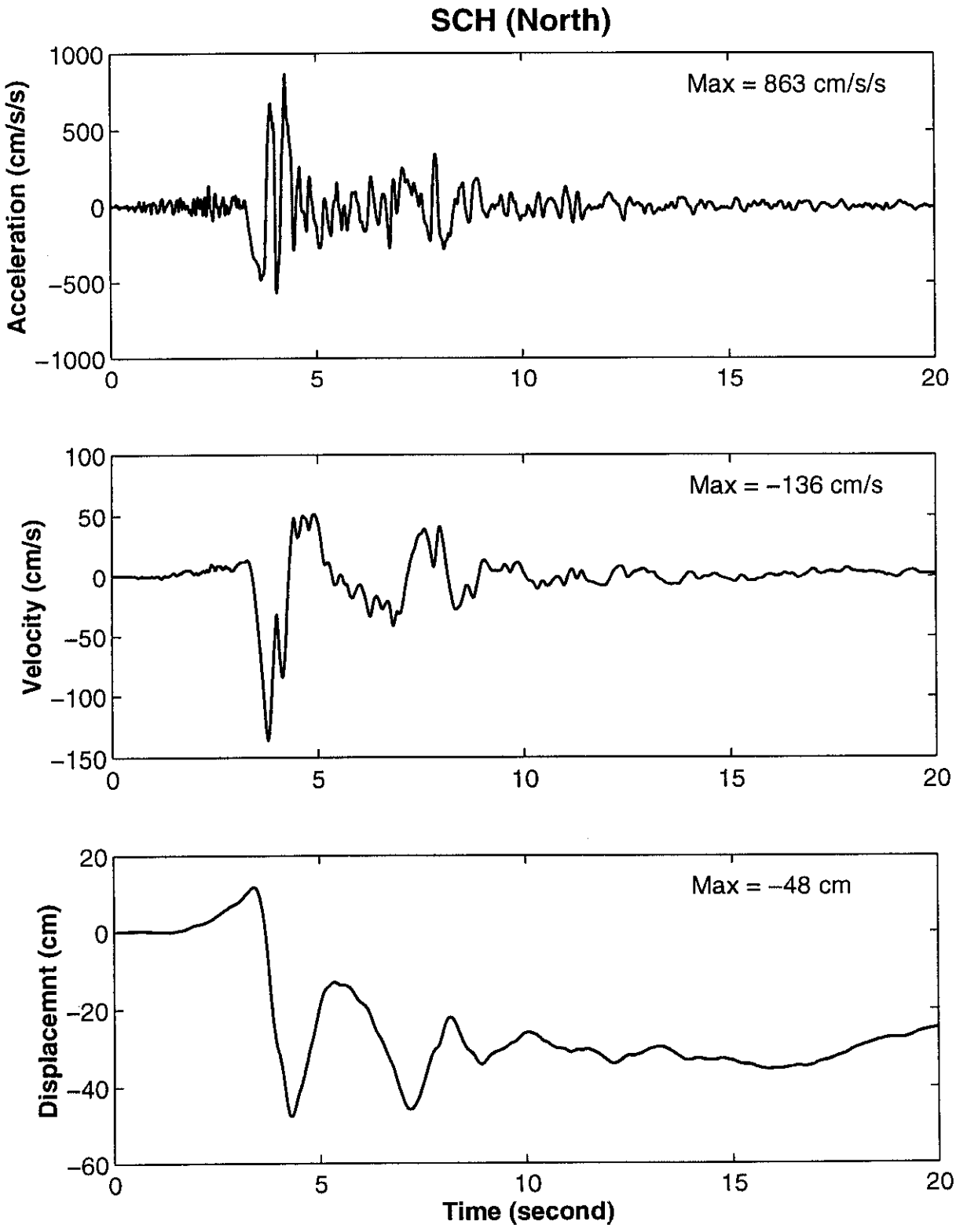

SCE (S22W)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %

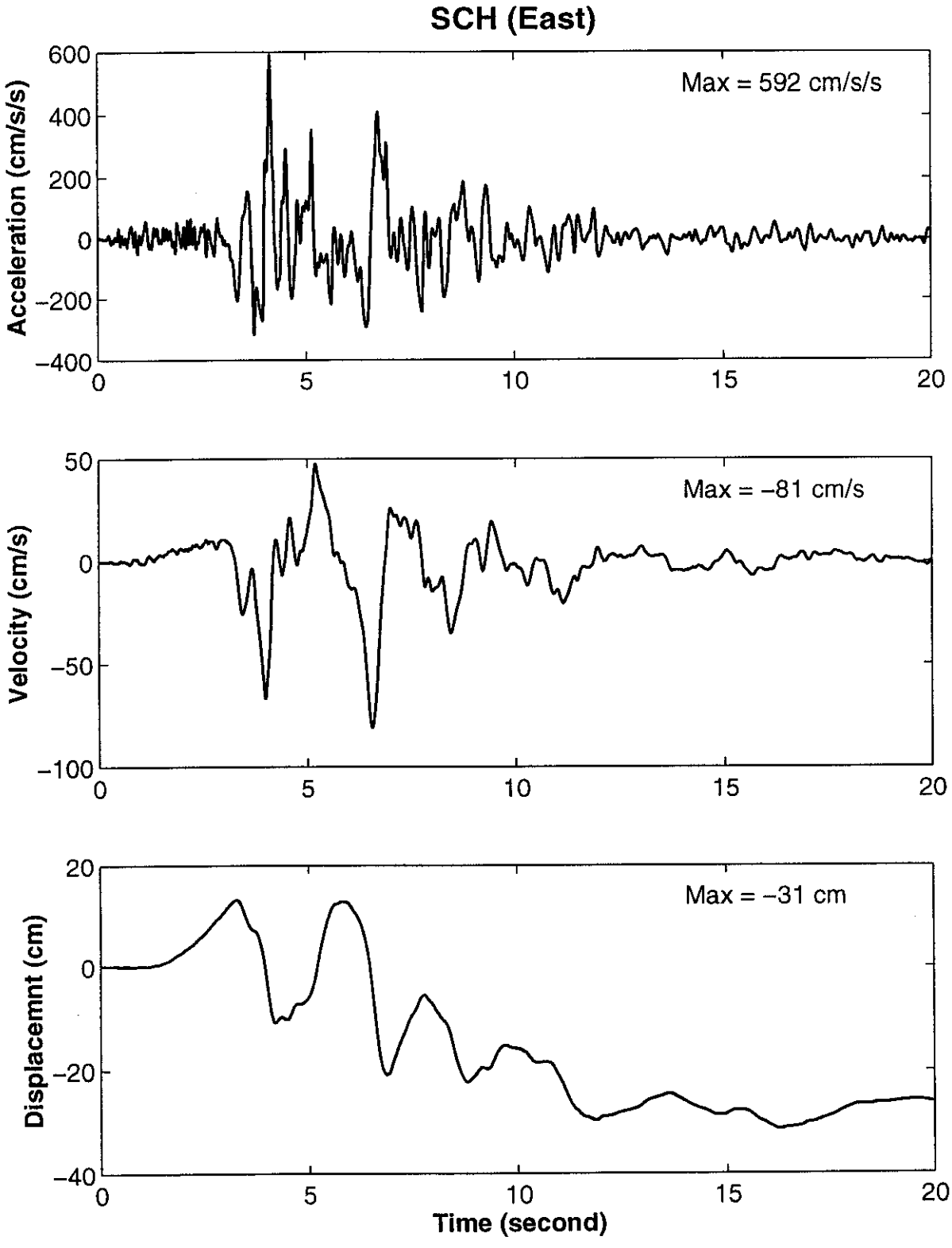

SCE (North)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5

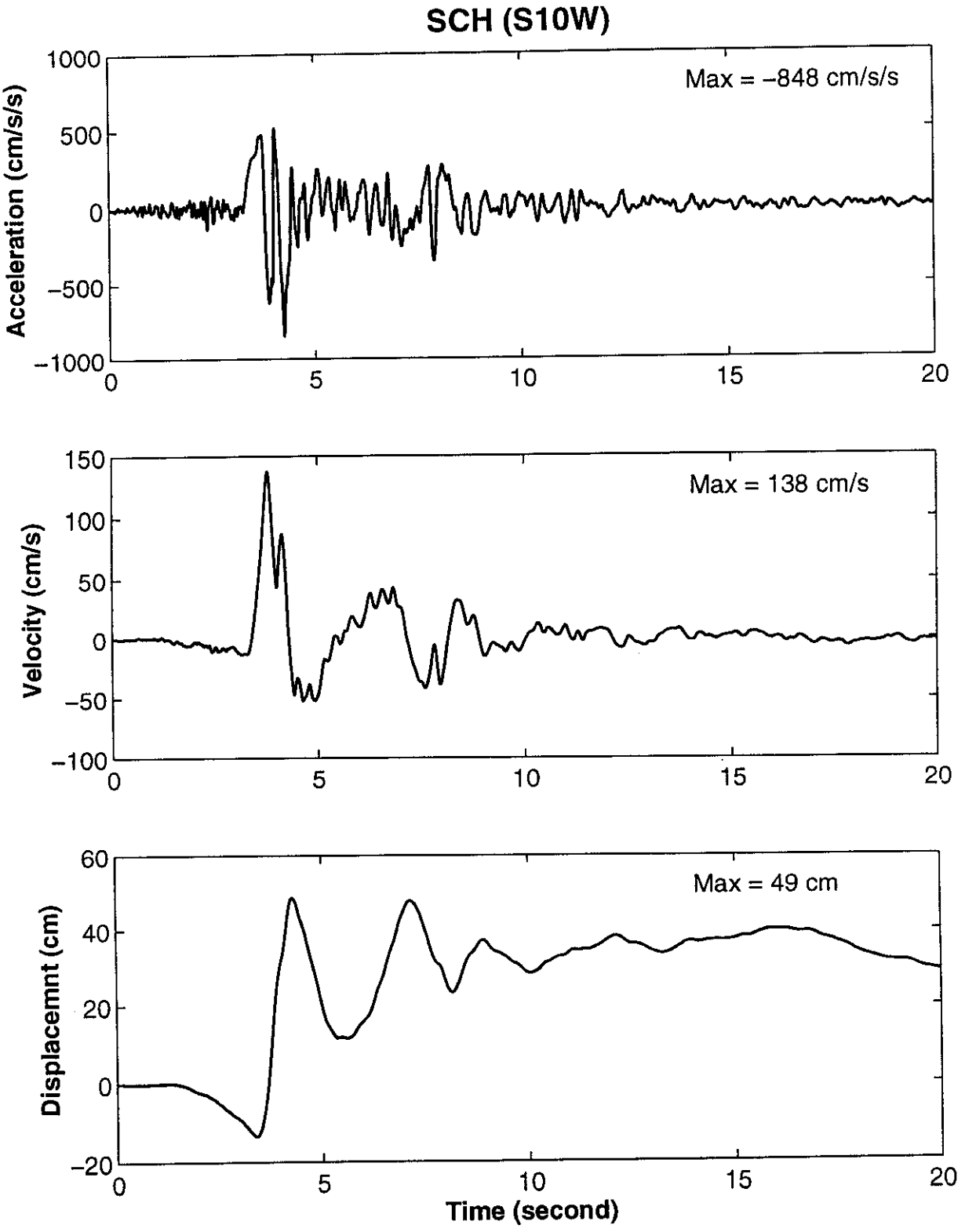

SCE (East)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5

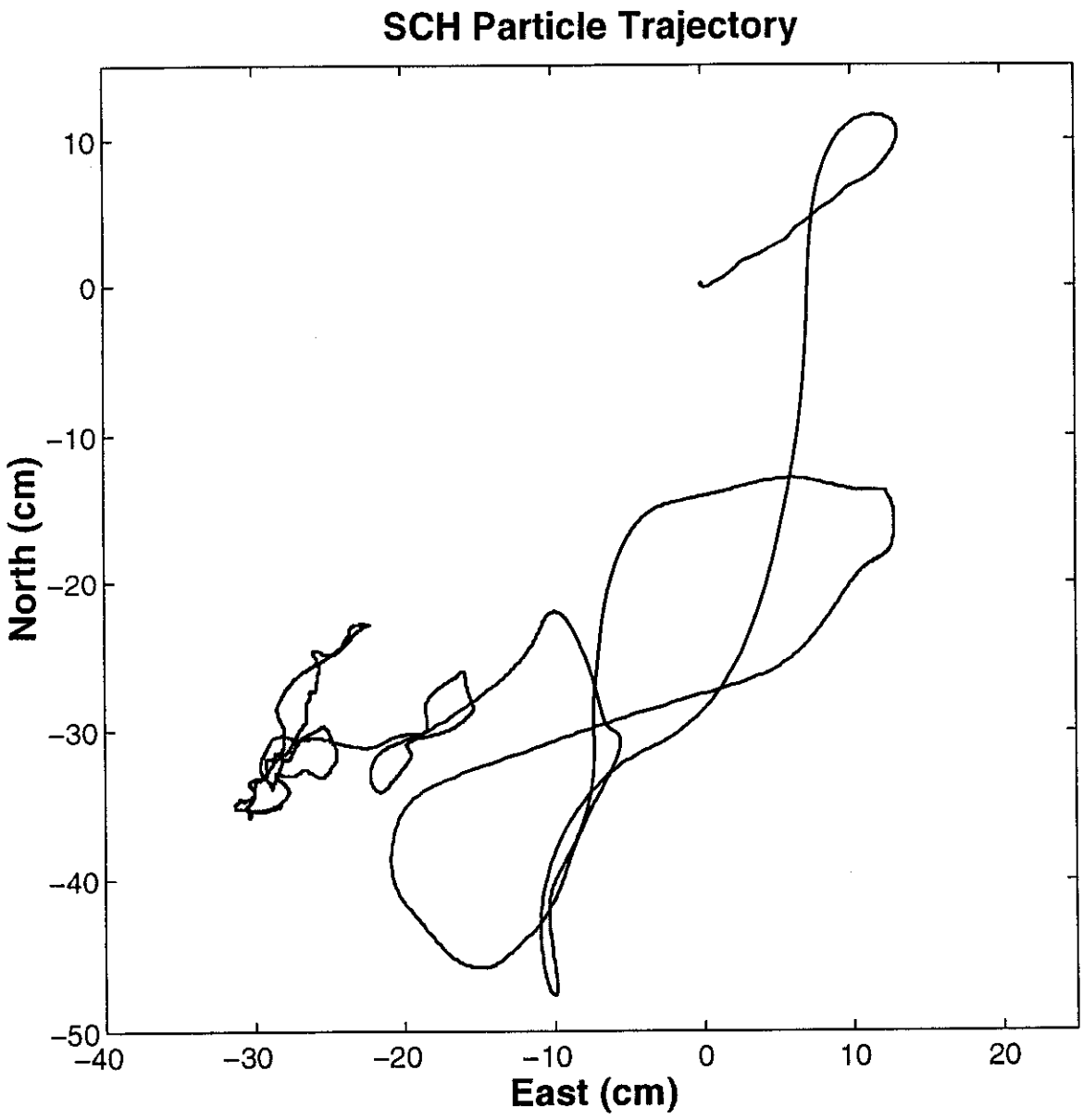

SCE (S22W)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5

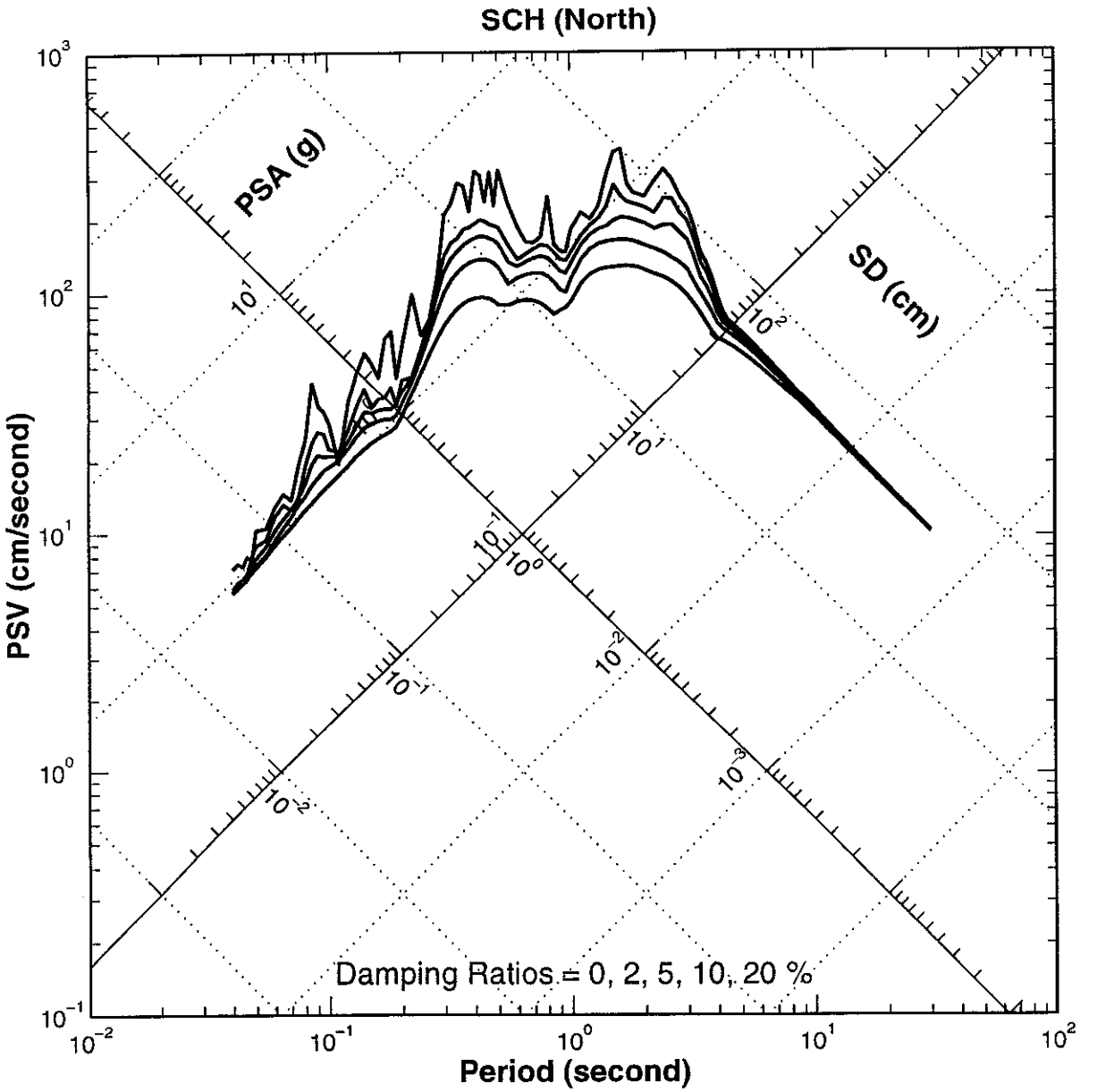
SYLMAR COUNTY HOSPITAL PARKING LOT (SCH)

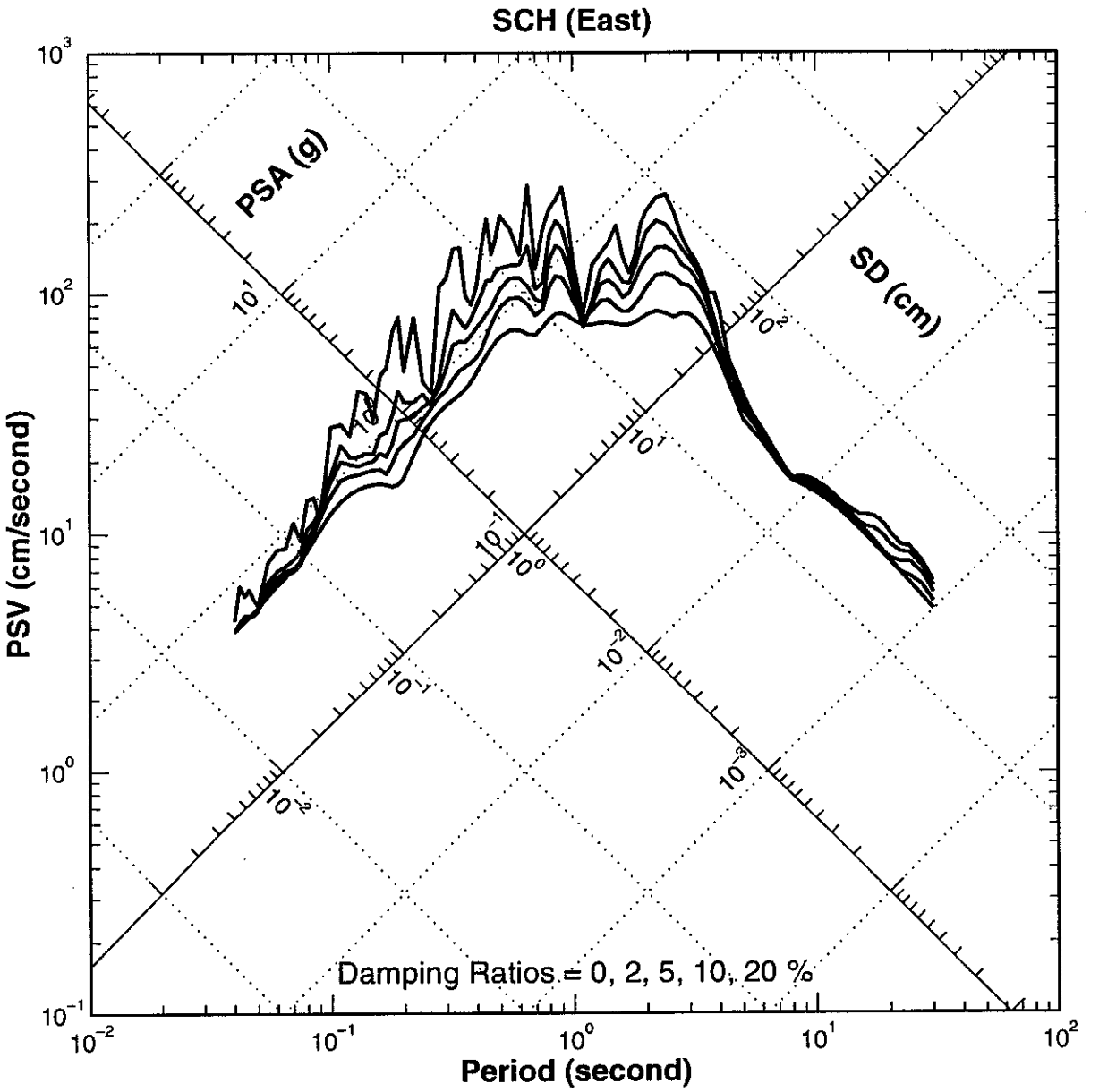

SCH (North)
Acceleration (cm/s/s)
Max = 863 cm/s/s
1000
500
0
−500
−1000
0
5
10
15
20
Velocity (cm/s)
Max = −136 cm/s
100
50
0
−50
−100
−150
Displacemnt (cm)
Max = −48 cm
20
0
−20
−40
−60
Time (second)

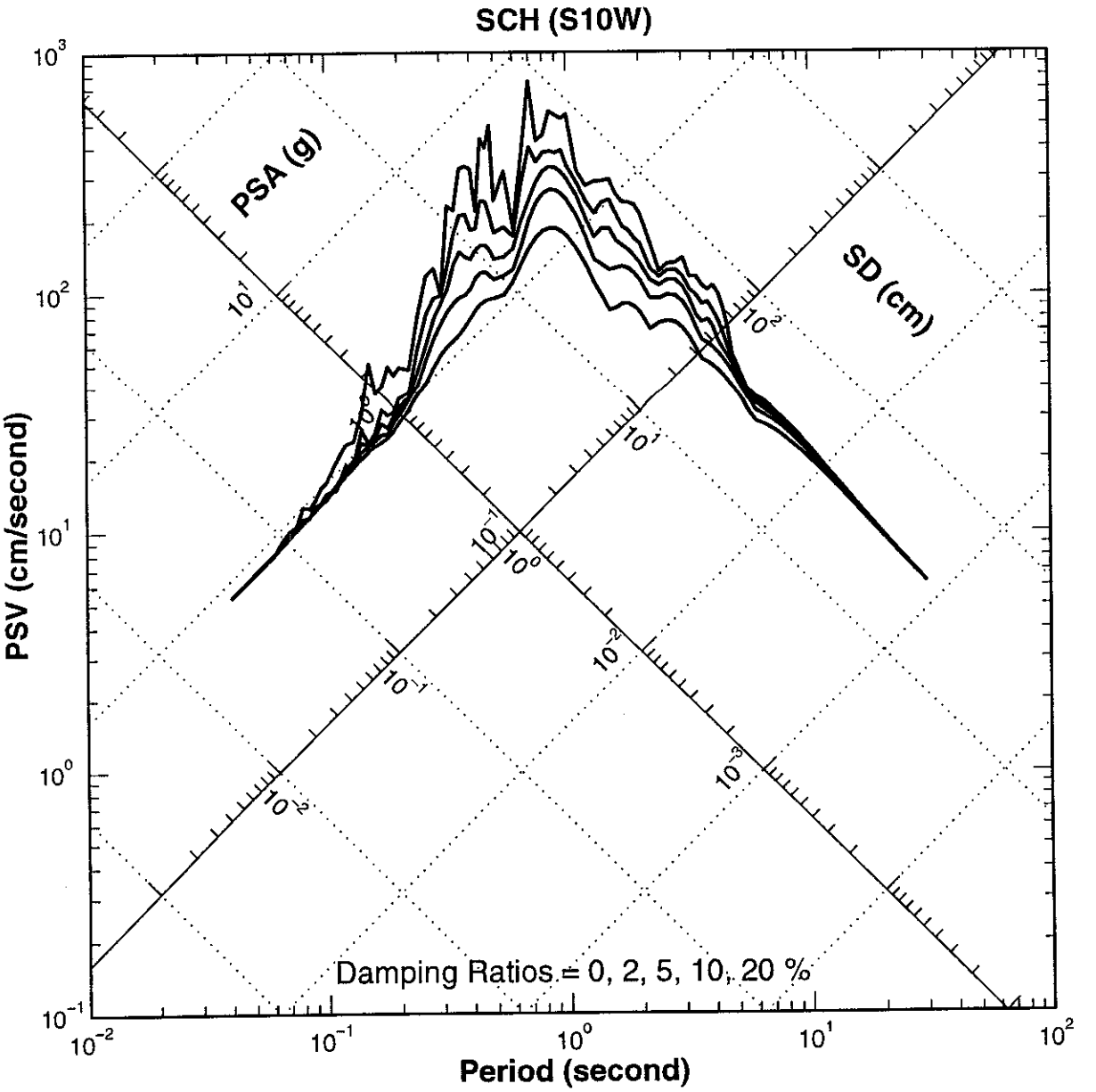

SCH (East)
Max = 592 cm/s/s
Acceleration (cm/s/s)
600
400
200
0
−200
−400
0
5
10
15
20
Max = −81 cm/s
Velocity (cm/s)
50
0
−50
−100
Max = −31 cm
Displacemnt (cm)
20
0
−20
−40
Time (second)

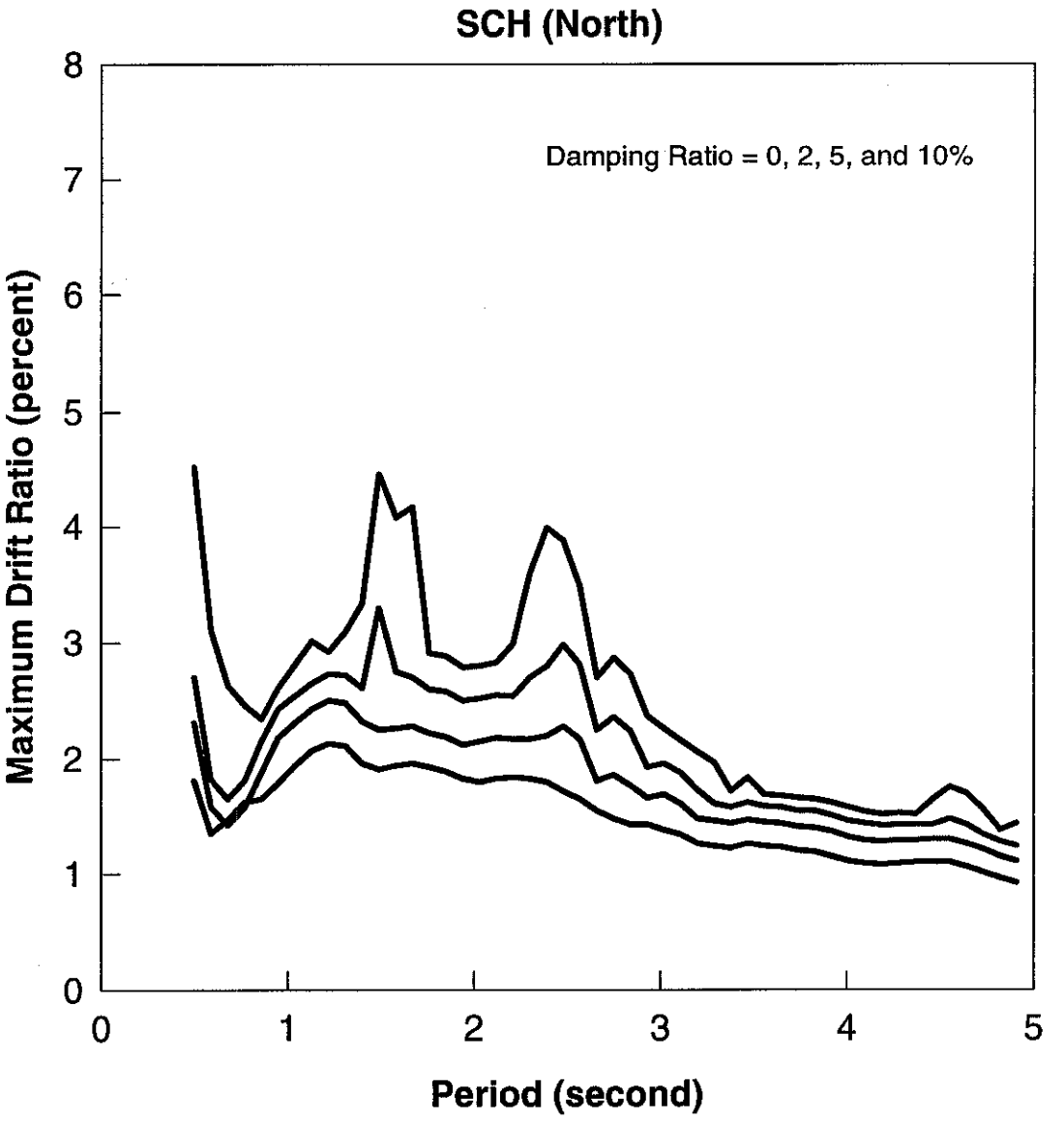

SCH (S10W)
Max = −848 cm/s/s
Acceleration (cm/s/s)
1000
500
0
−500
−1000
0
5
10
15
20
Max = 138 cm/s
Velocity (cm/s)
150
100
50
0
−50
−100
Max = 49 cm
Displacemnt (cm)
60
40
20
0
−20
Time (second)

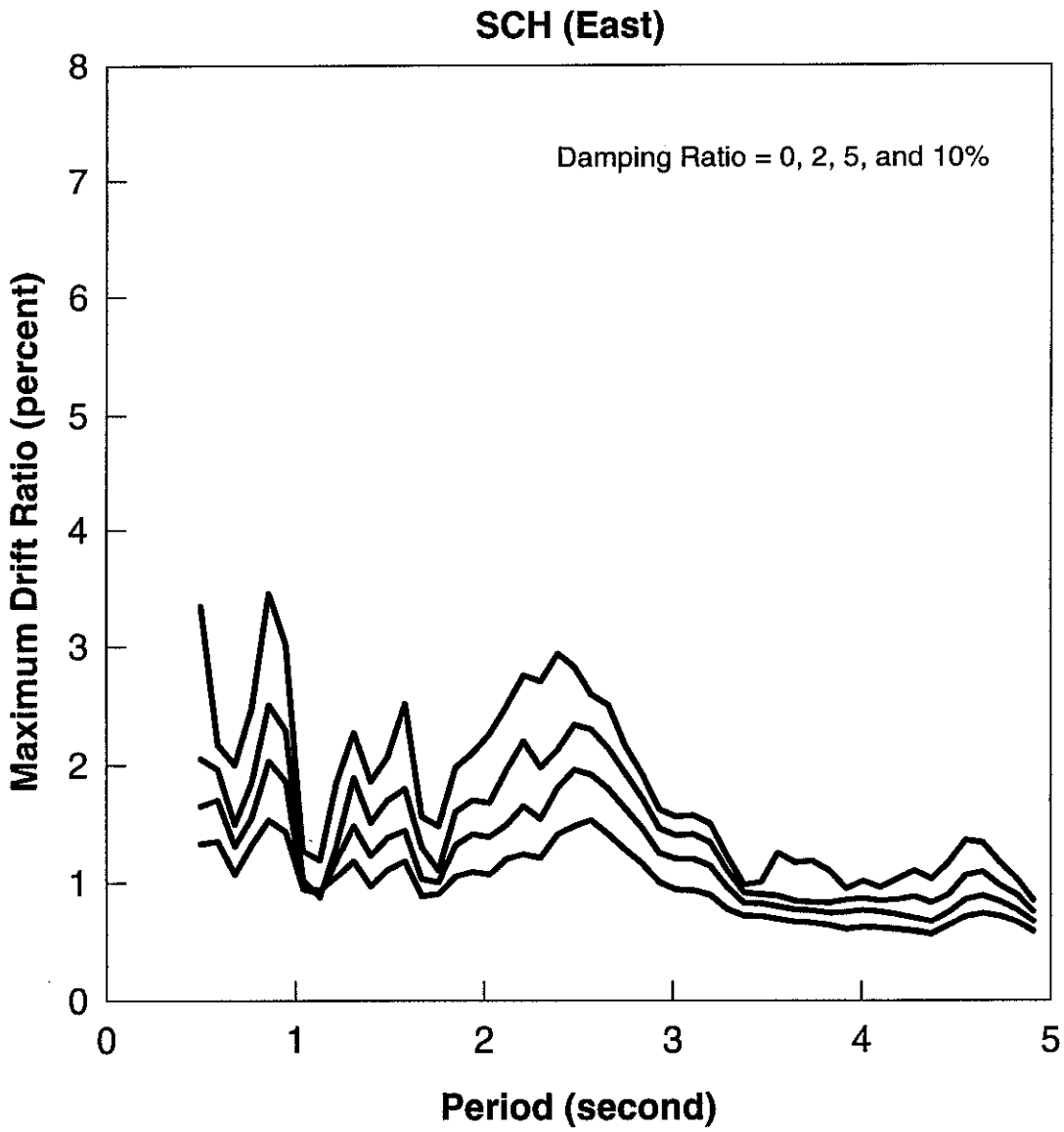

SCH Particle Trajectory
North (cm)
East (cm)
10
0
−10
−20
−30
−40
−50
−40
−30
−20
−10
0
10
20

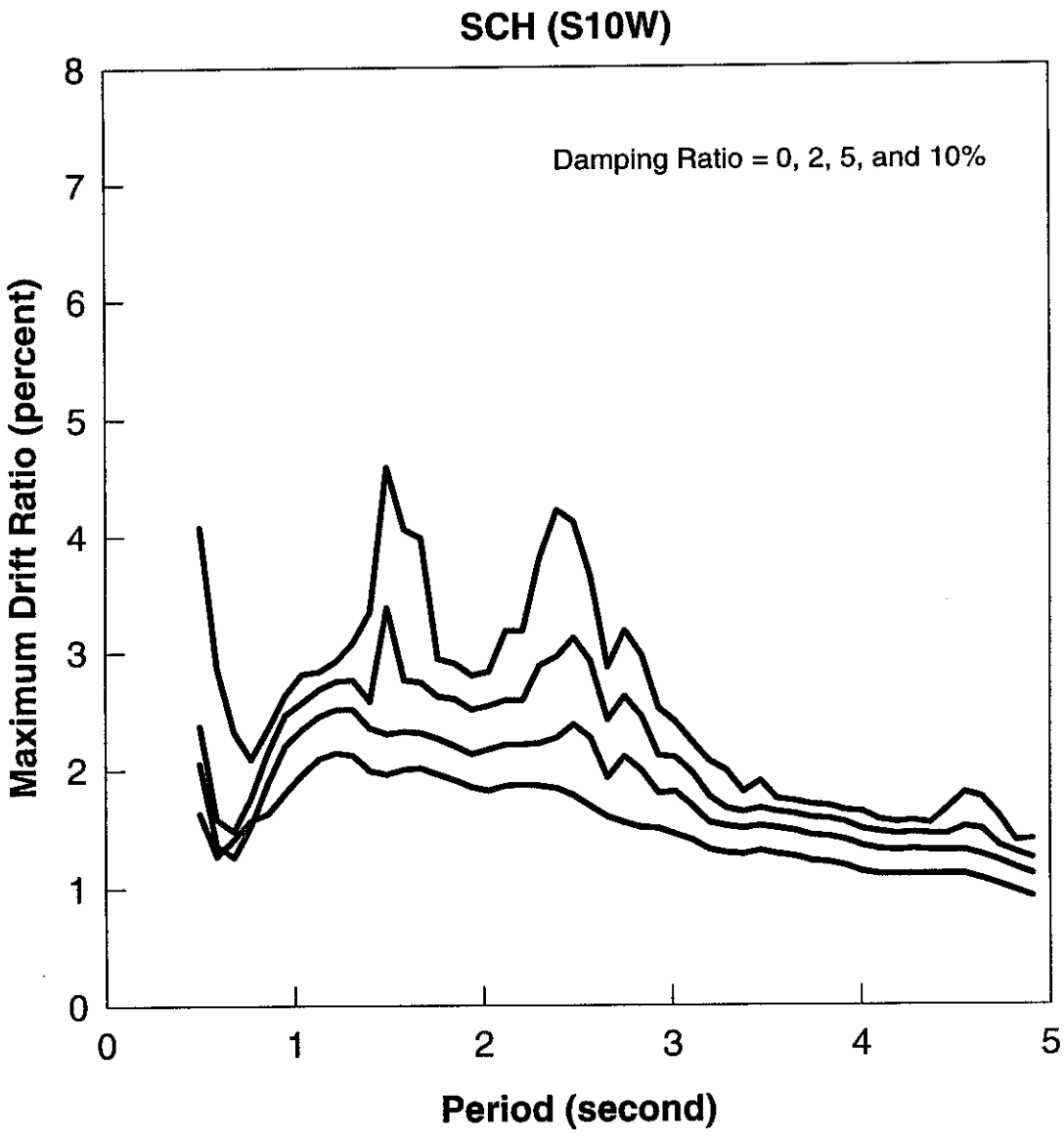

SCH (North)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %


SCH (East)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %

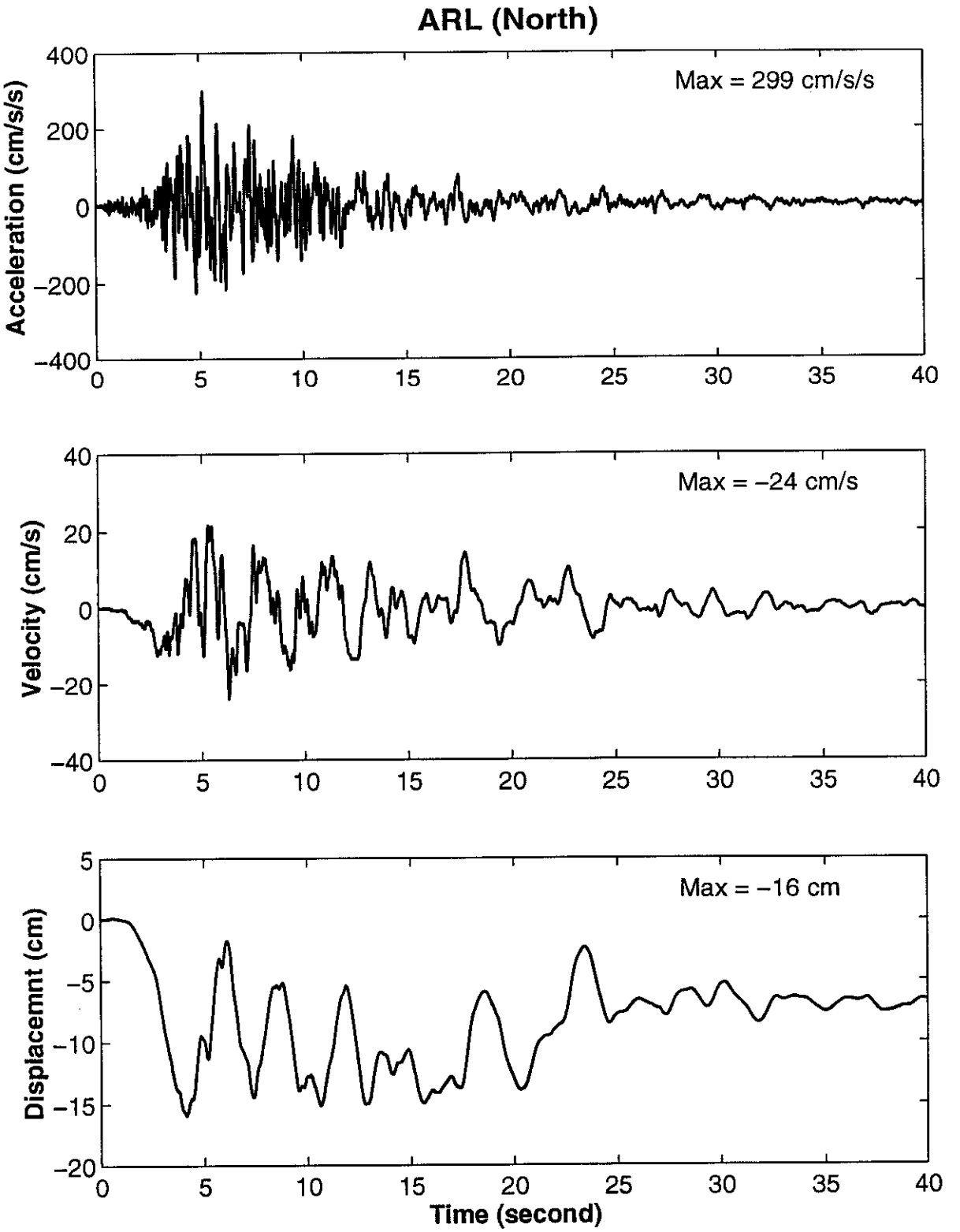

SCH (S10W)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %

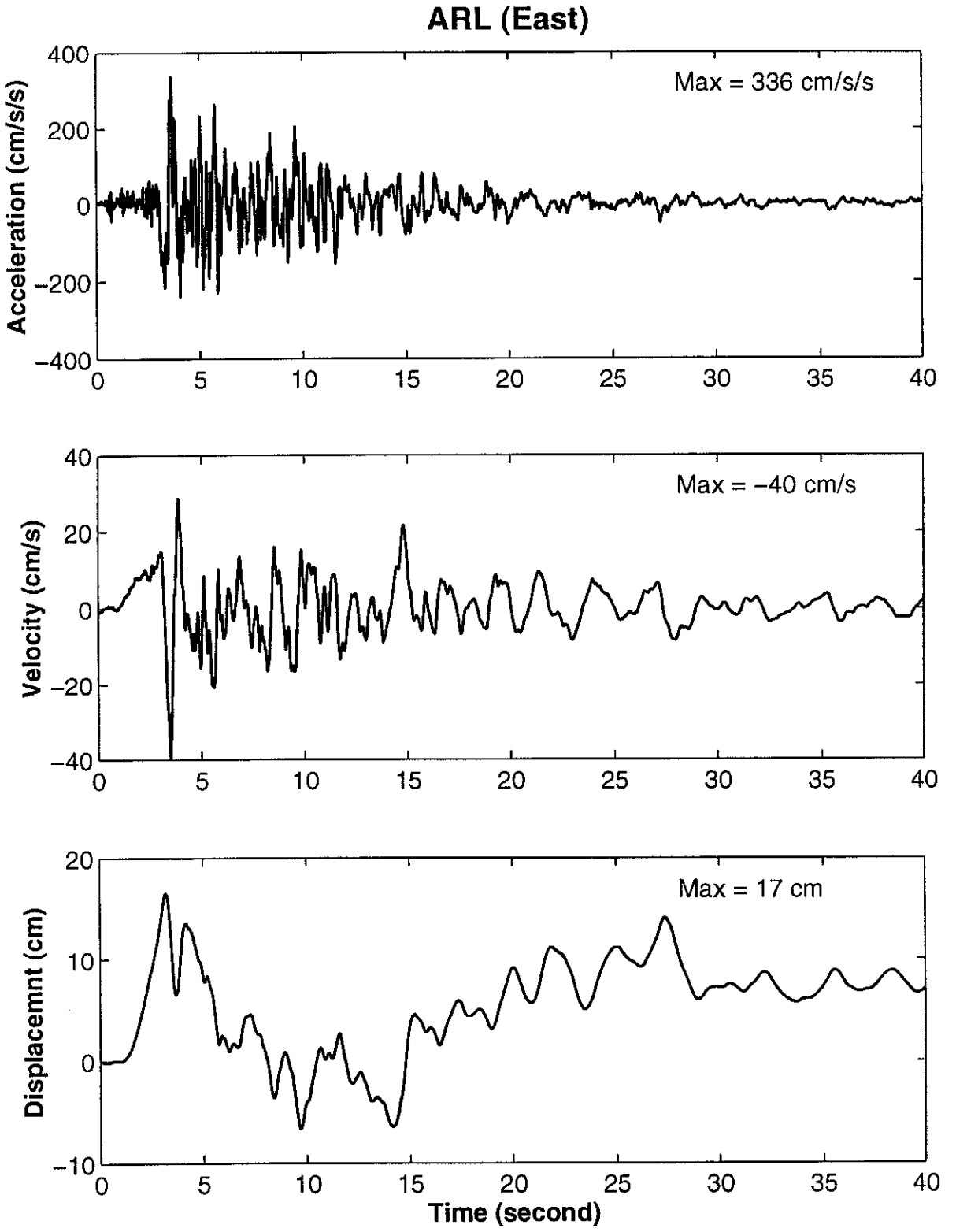

SCH (North)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5

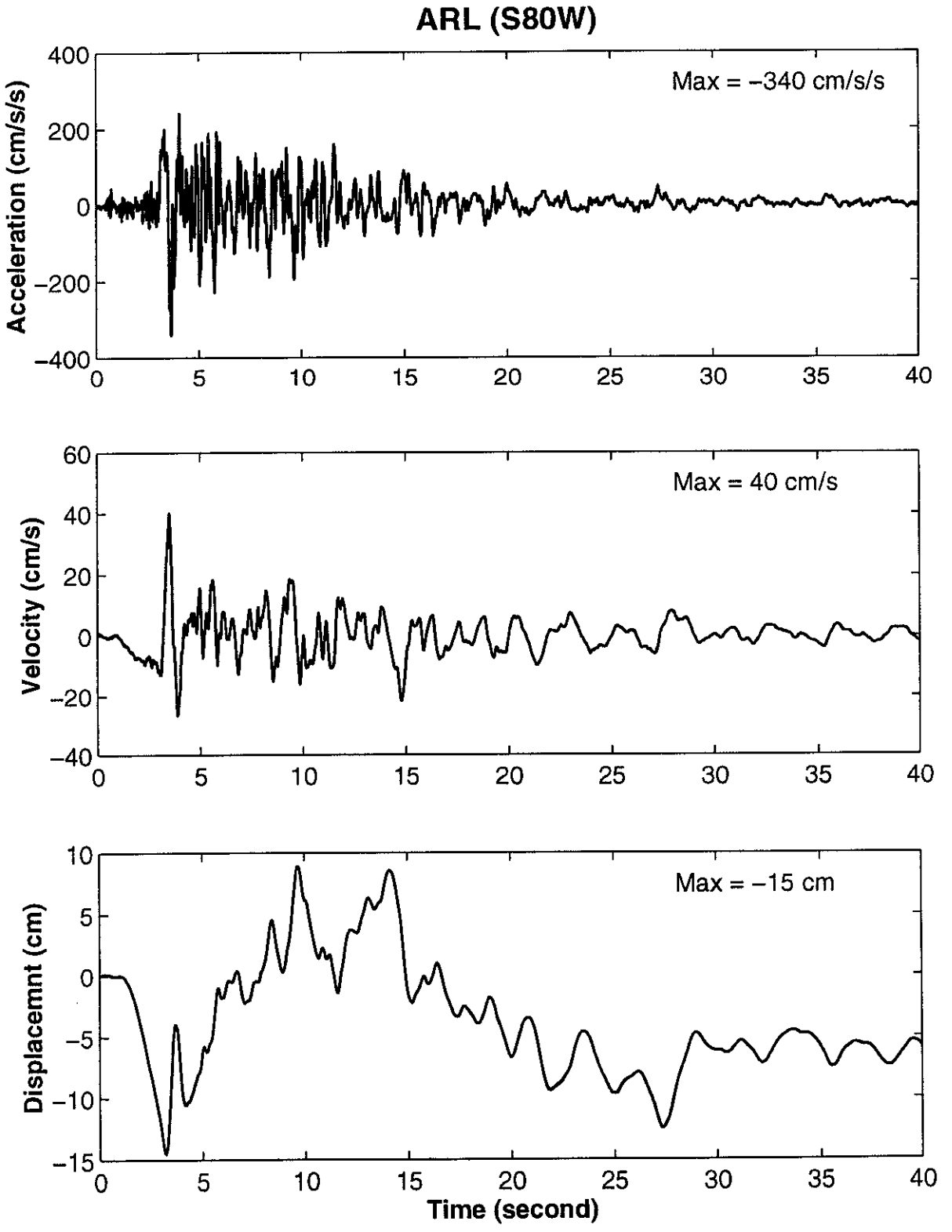

SCH (East)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5

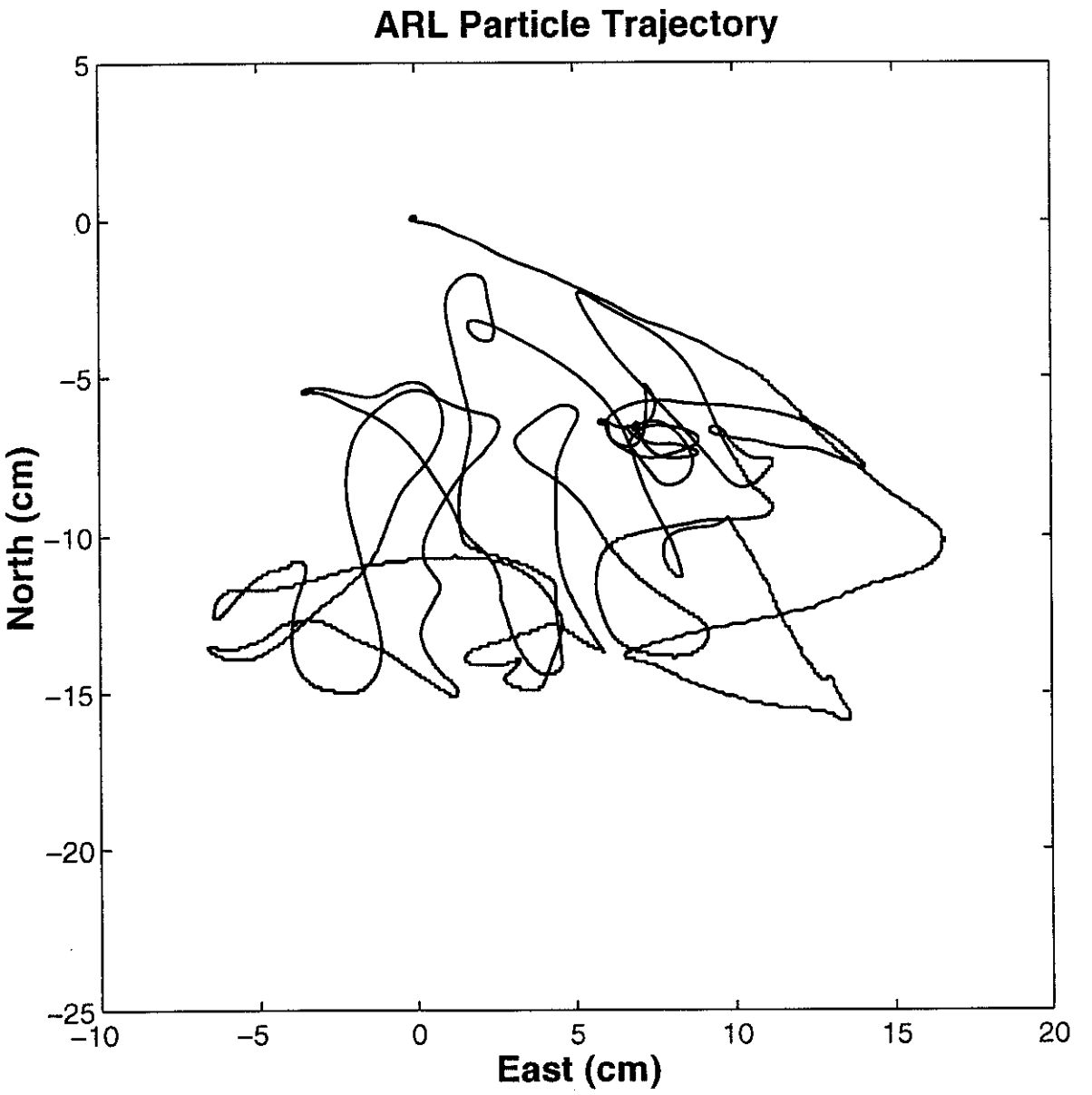

SCH (S10W)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5

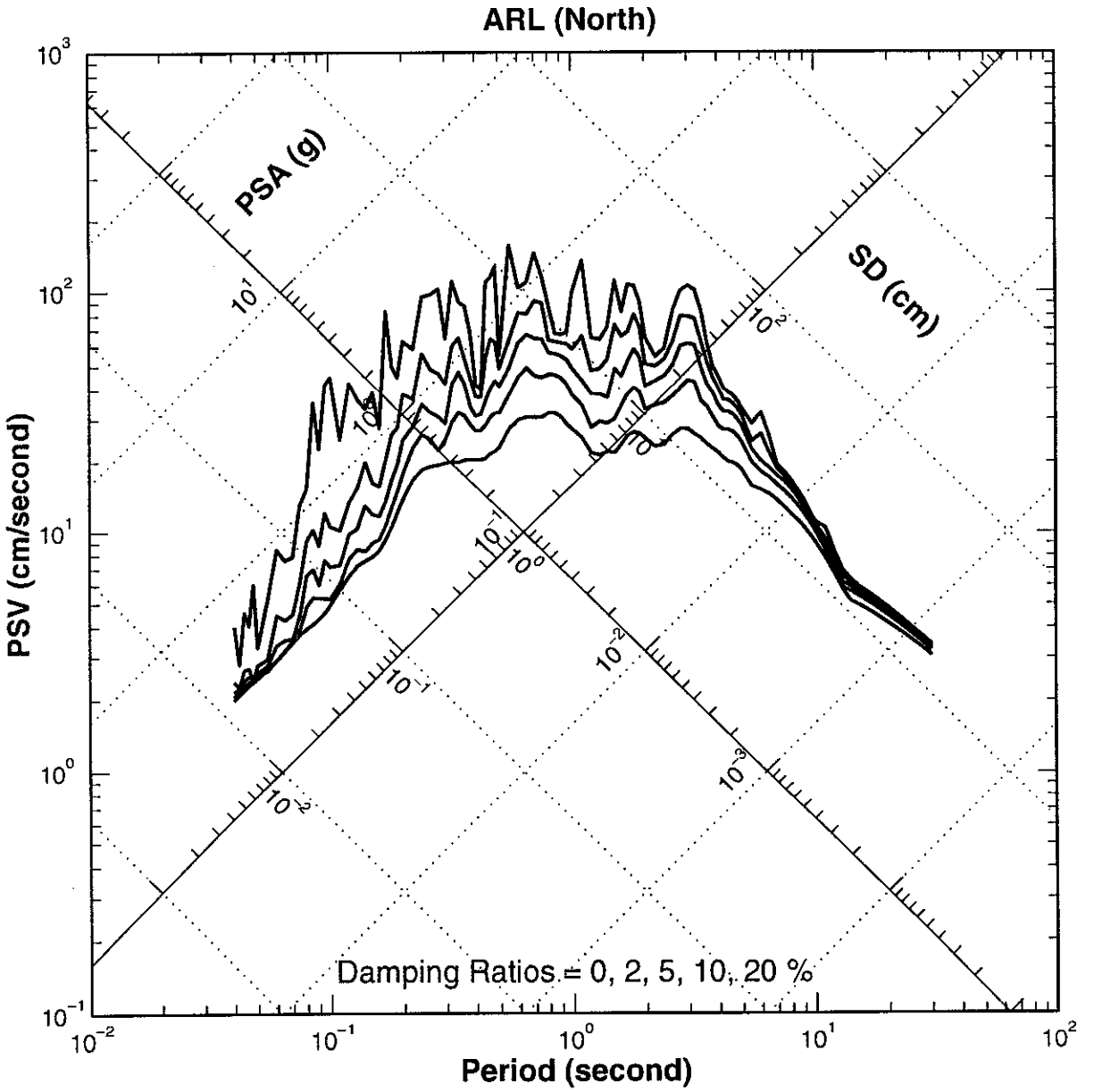
ARLETA NORDHOFF AVENUE FIRE STATION (ARL)

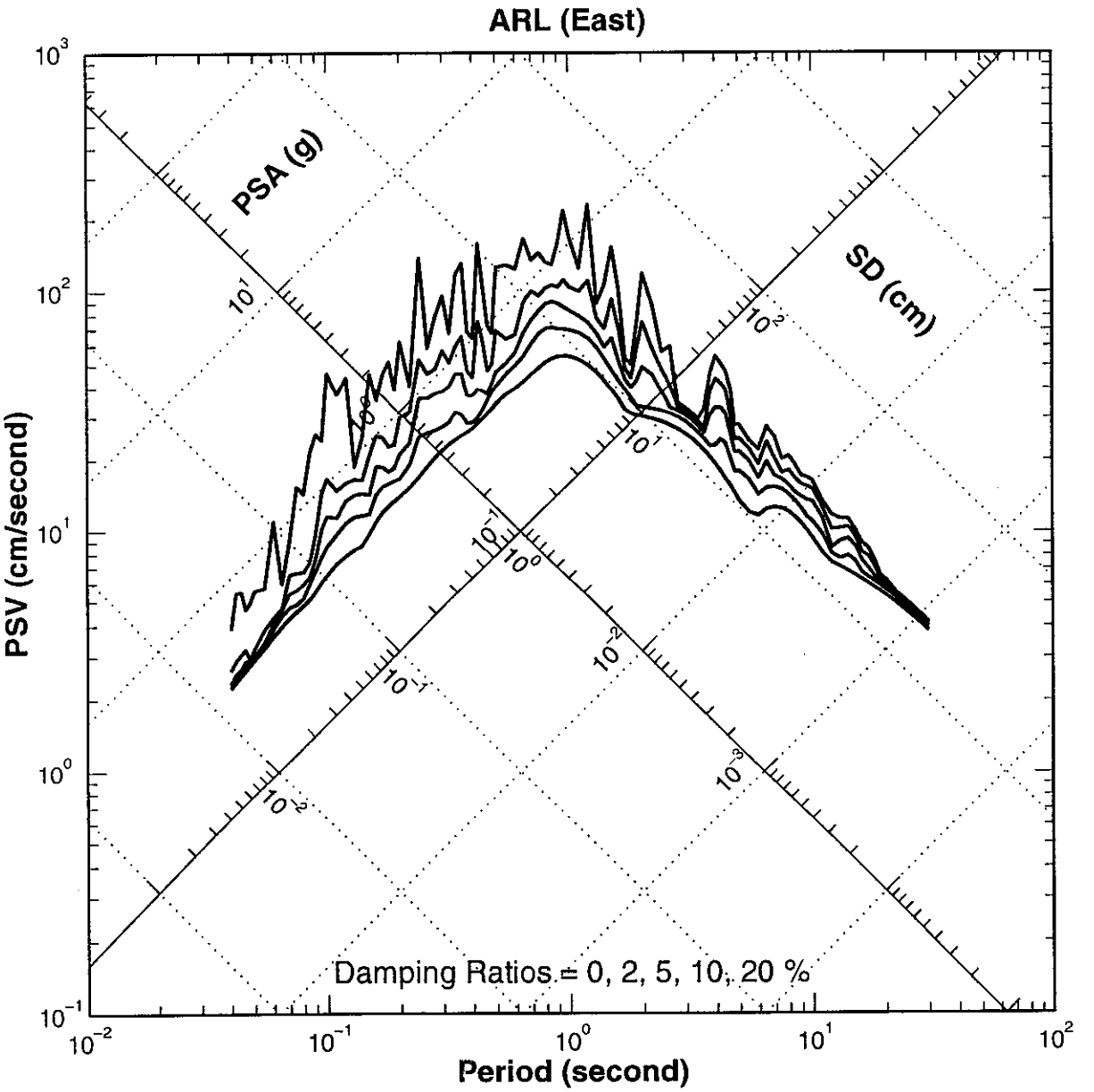

ARL (North)
Max = 299 cm/s/s
Acceleration (cm/s/s)
400
200
0
−200
−400
Max = −24 cm/s
Velocity (cm/s)
40
20
0
−20
−40
Max = −16 cm
Displacemnt (cm)
5
0
−5
−10
−15
−20
0
5
10
15
20
25
30
35
40
Time (second)

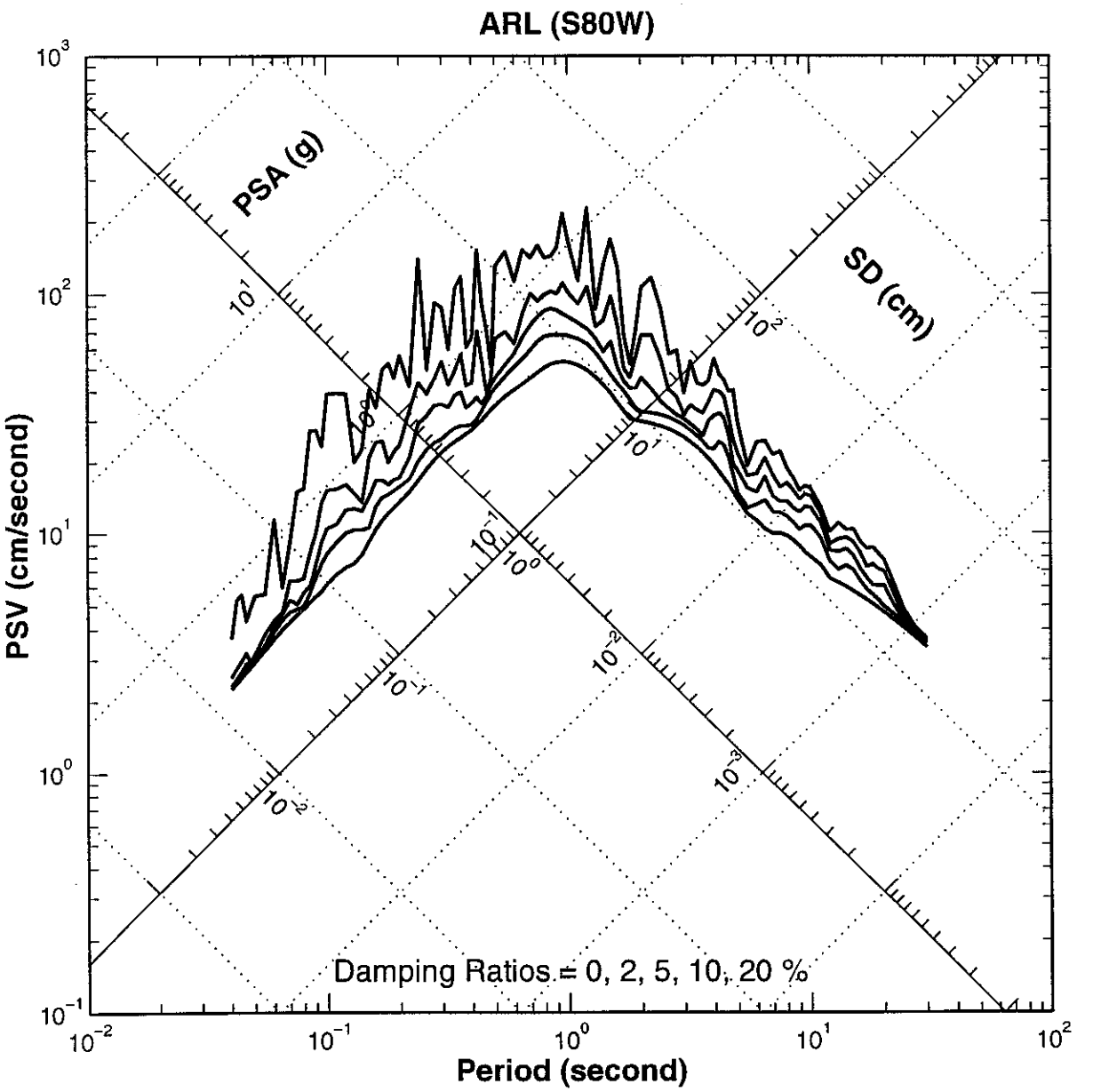

ARL (East)
Max = 336 cm/s/s
Acceleration (cm/s/s)
400
200
0
−200
−400
Max = −40 cm/s
Velocity (cm/s)
40
20
0
−20
−40
Max = 17 cm
Displacemnt (cm)
20
10
0
−10
0
5
10
15
20
25
30
35
40
Time (second)

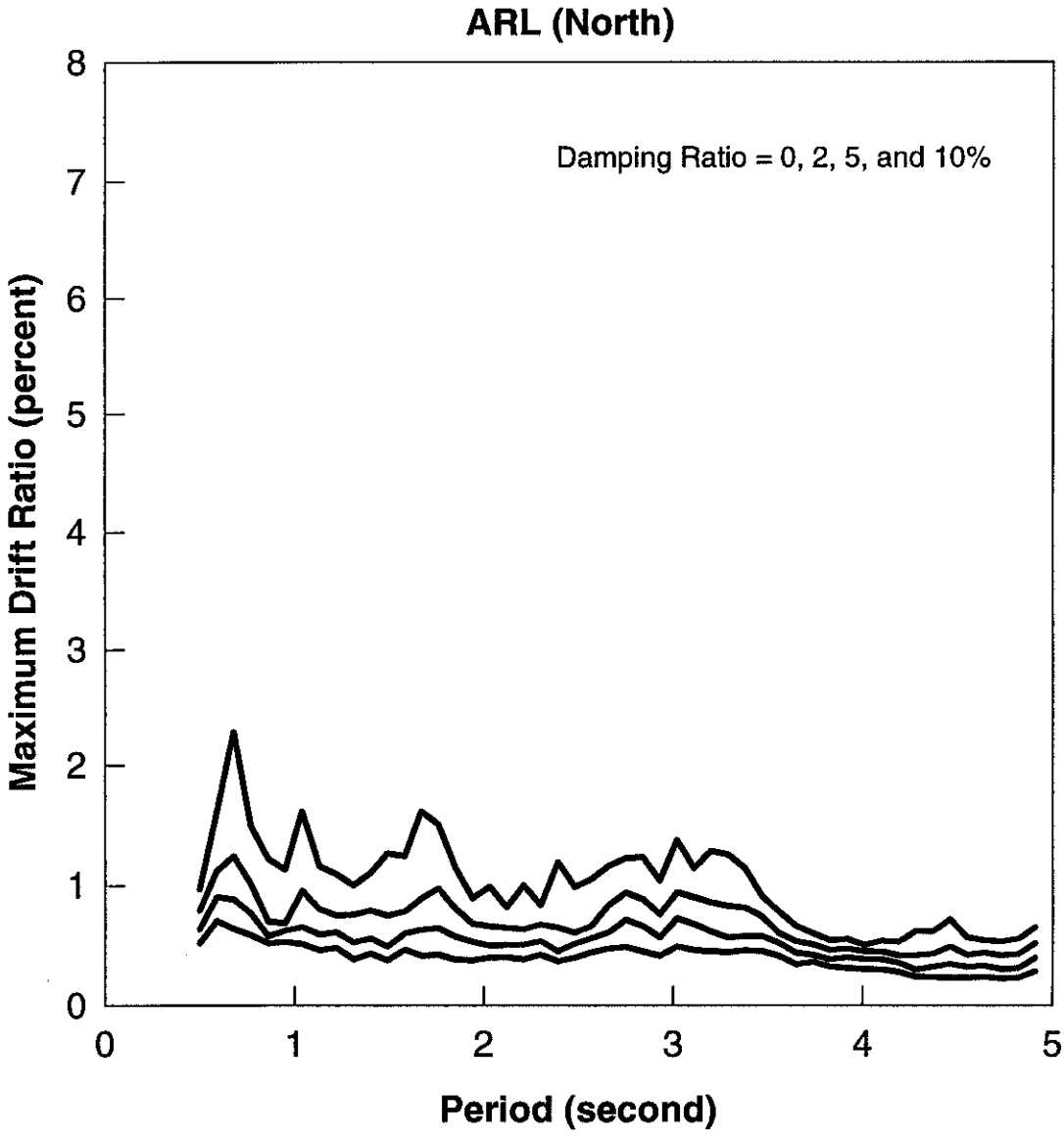

ARL (S80W)
Max = −340 cm/s/s
Acceleration (cm/s/s)
400
200
0
−200
−400
0
5
10
15
20
25
30
35
40
Max = 40 cm/s
Velocity (cm/s)
60
40
20
0
−20
−40
Max = −15 cm
Displacemnt (cm)
10
5
0
−5
−10
−15
Time (second)

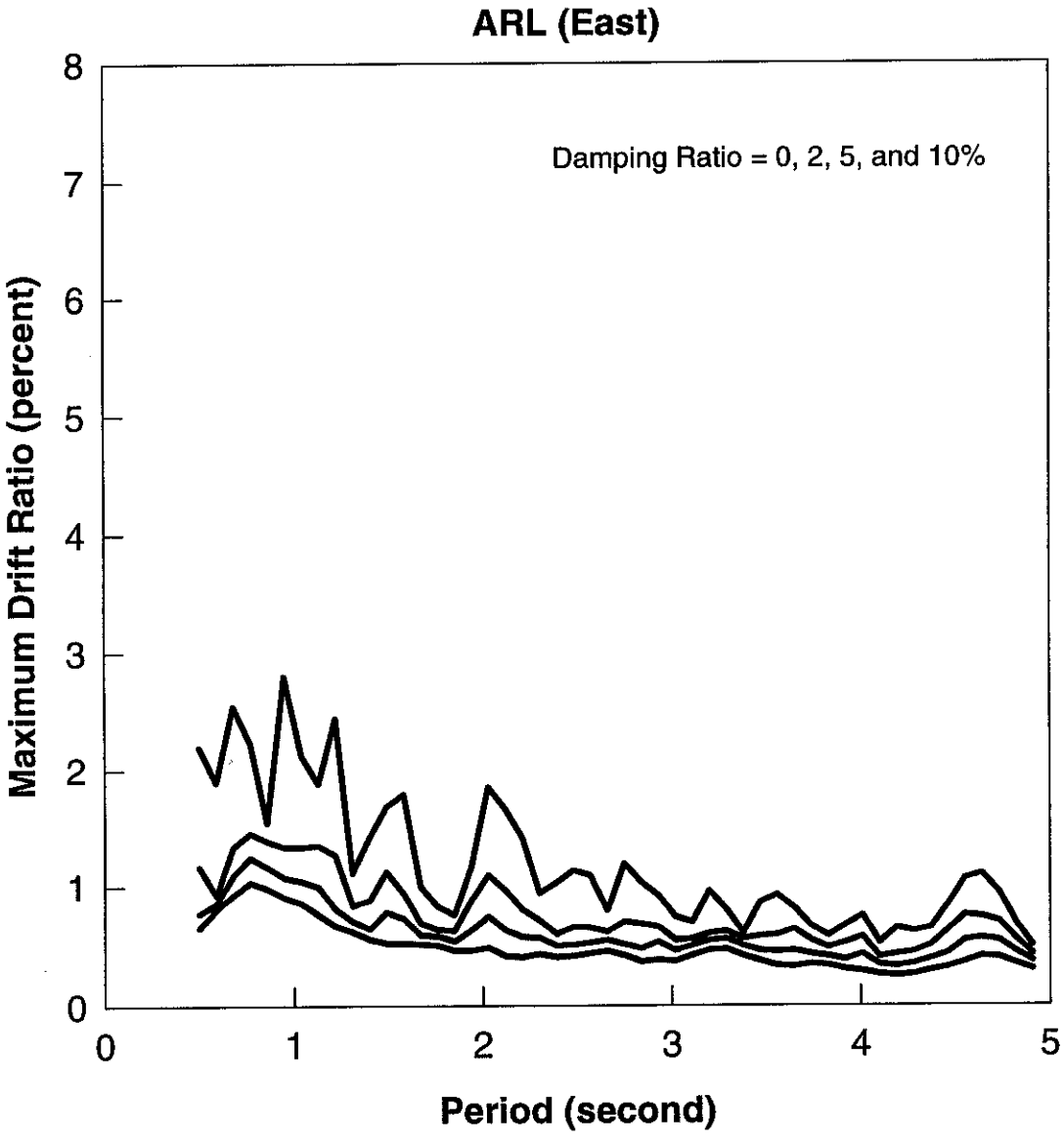

ARL Particle Trajectory
North (cm)
East (cm)
5
0
−5
−10
−15
−20
−25
−10
−5
0
5
10
15
20

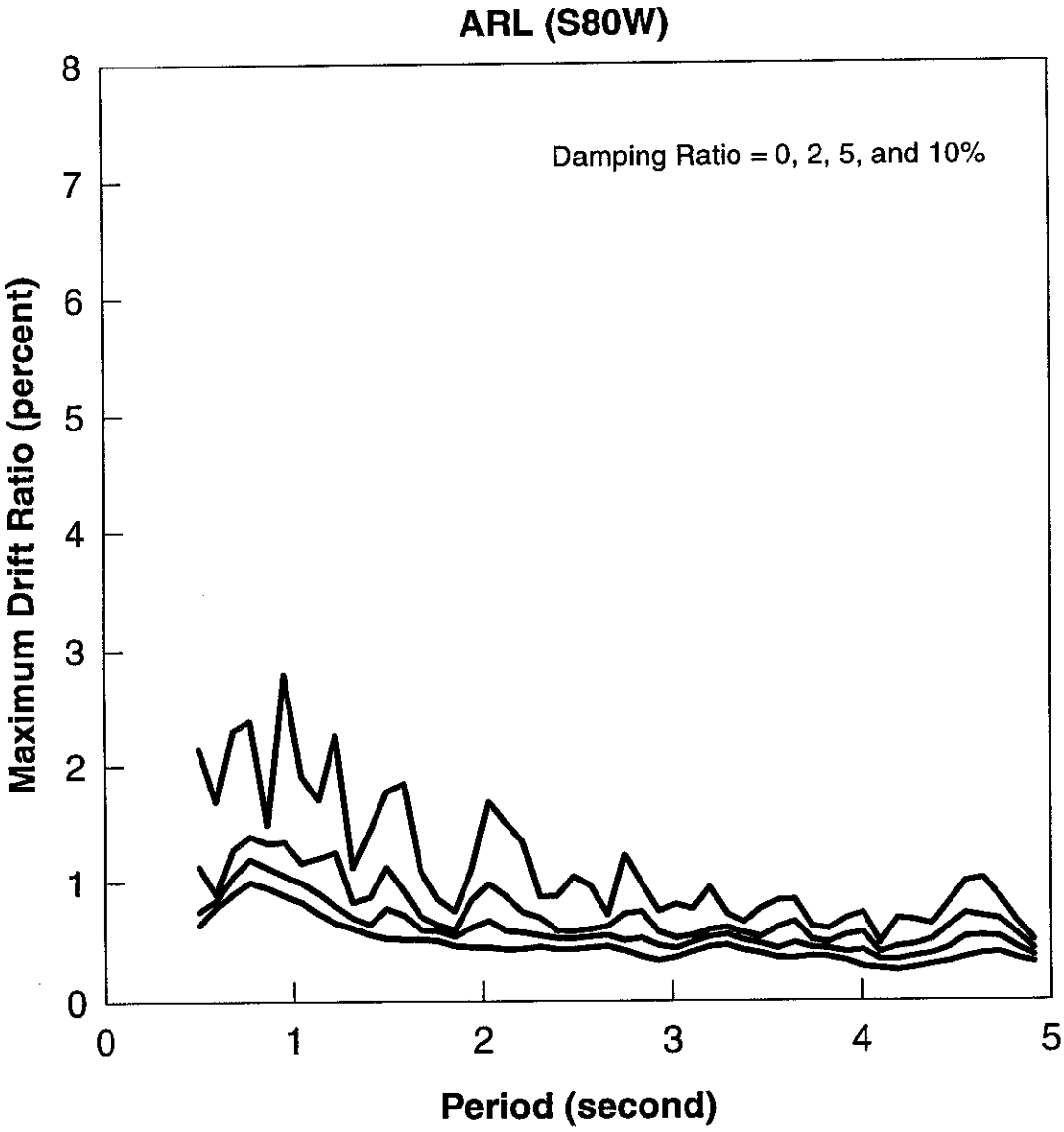

ARL (North)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %


ARL (East)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %

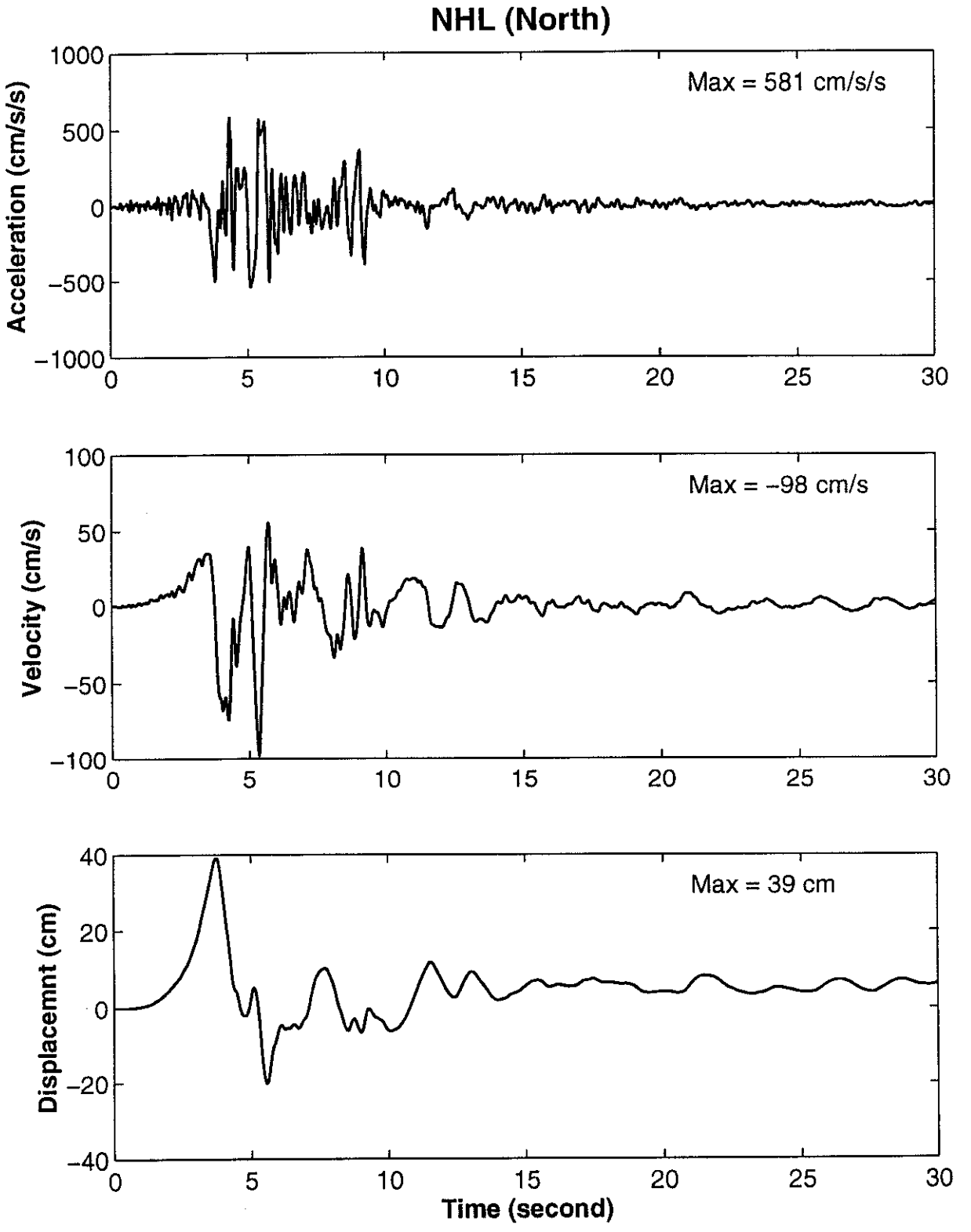

ARL (S80W)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %

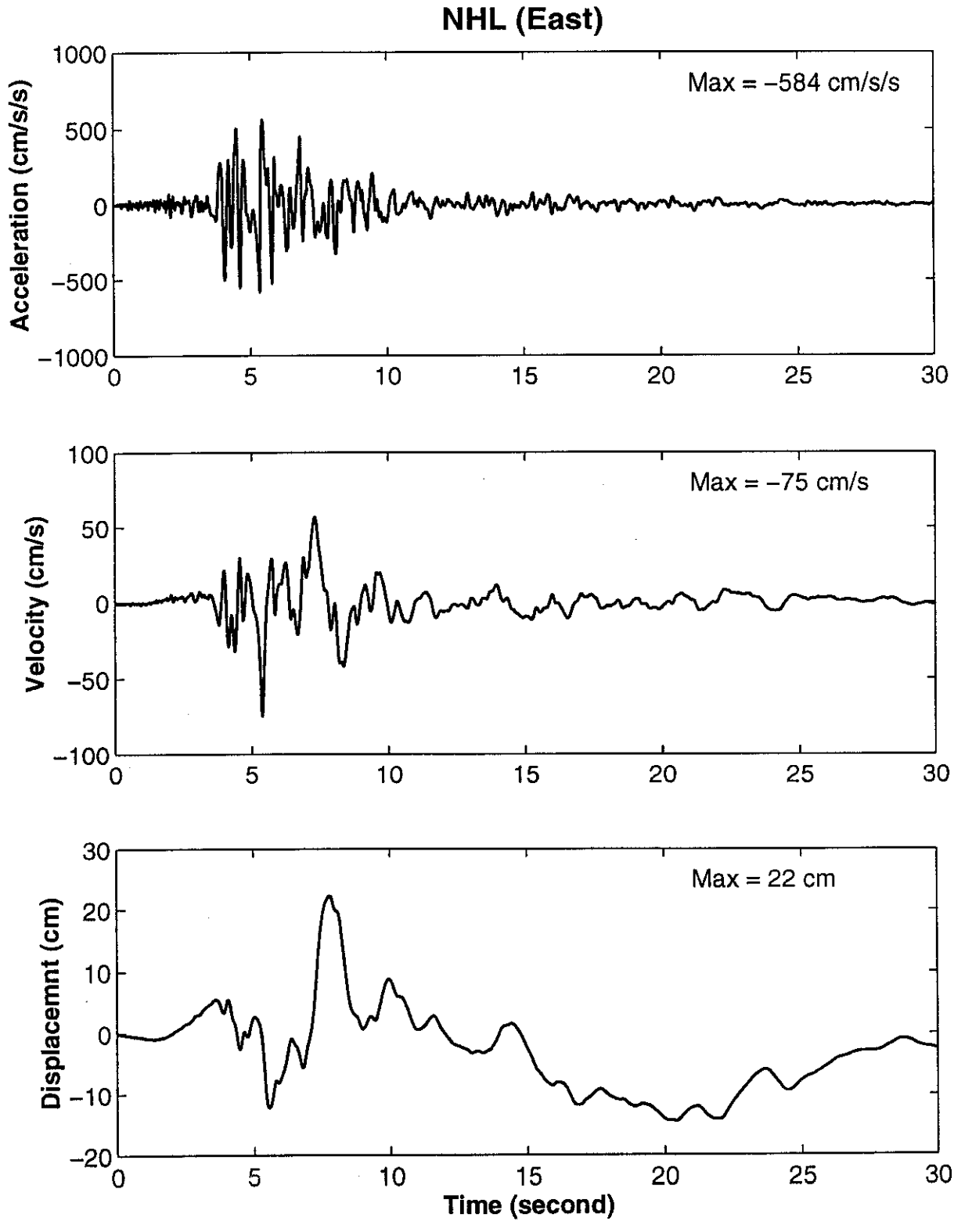

ARL (North)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5

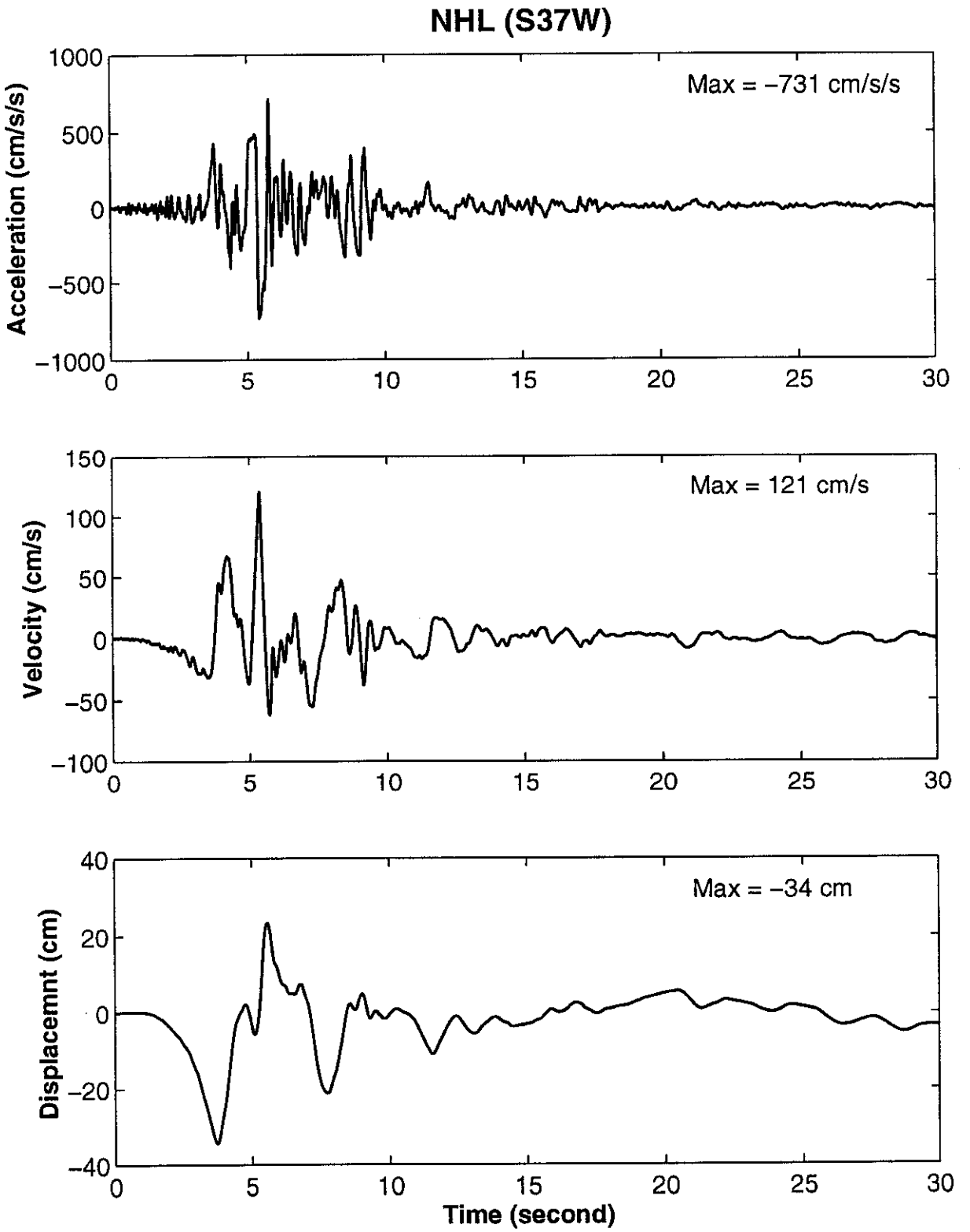

ARL (East)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5

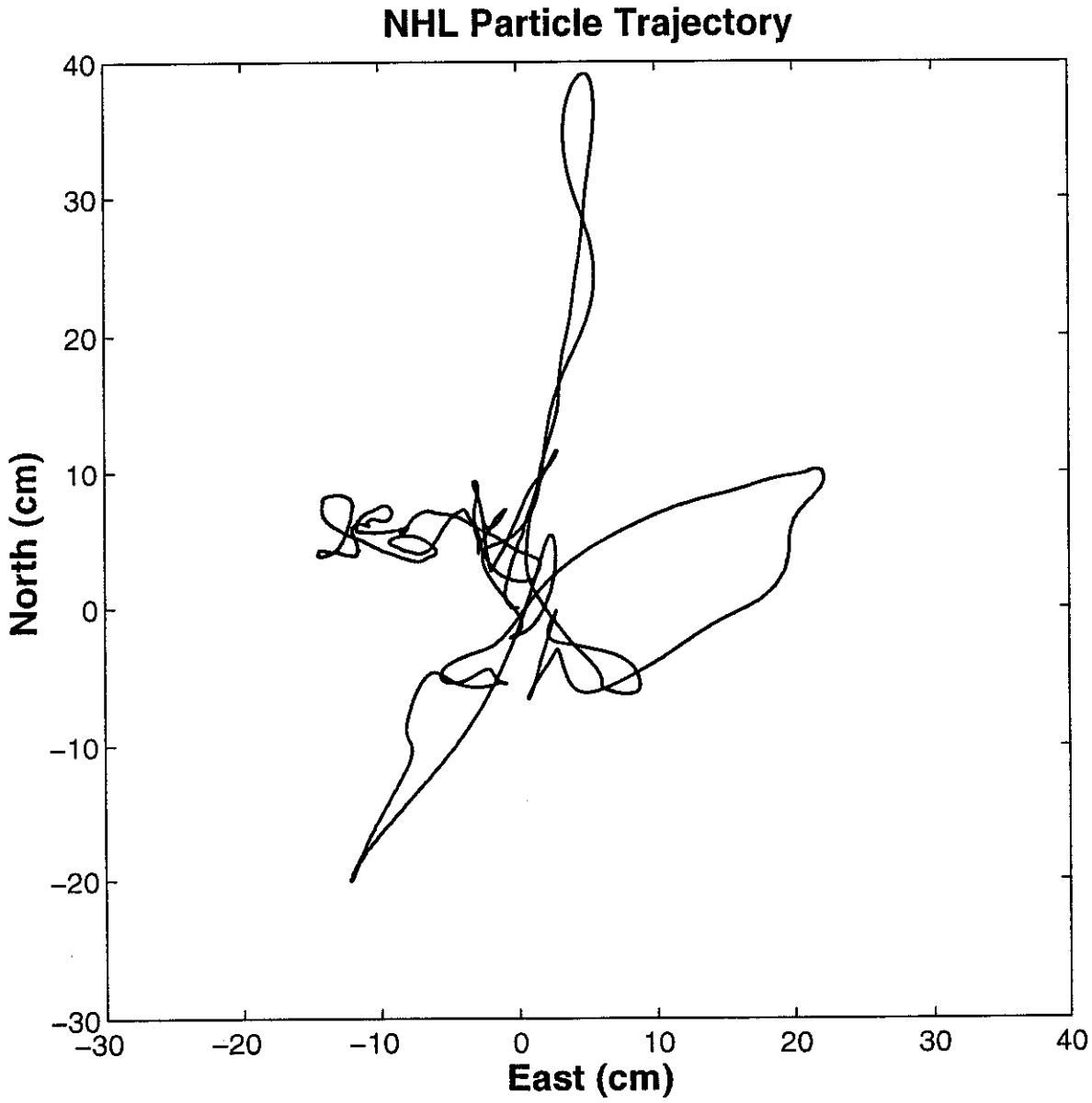

ARL (S80W)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5

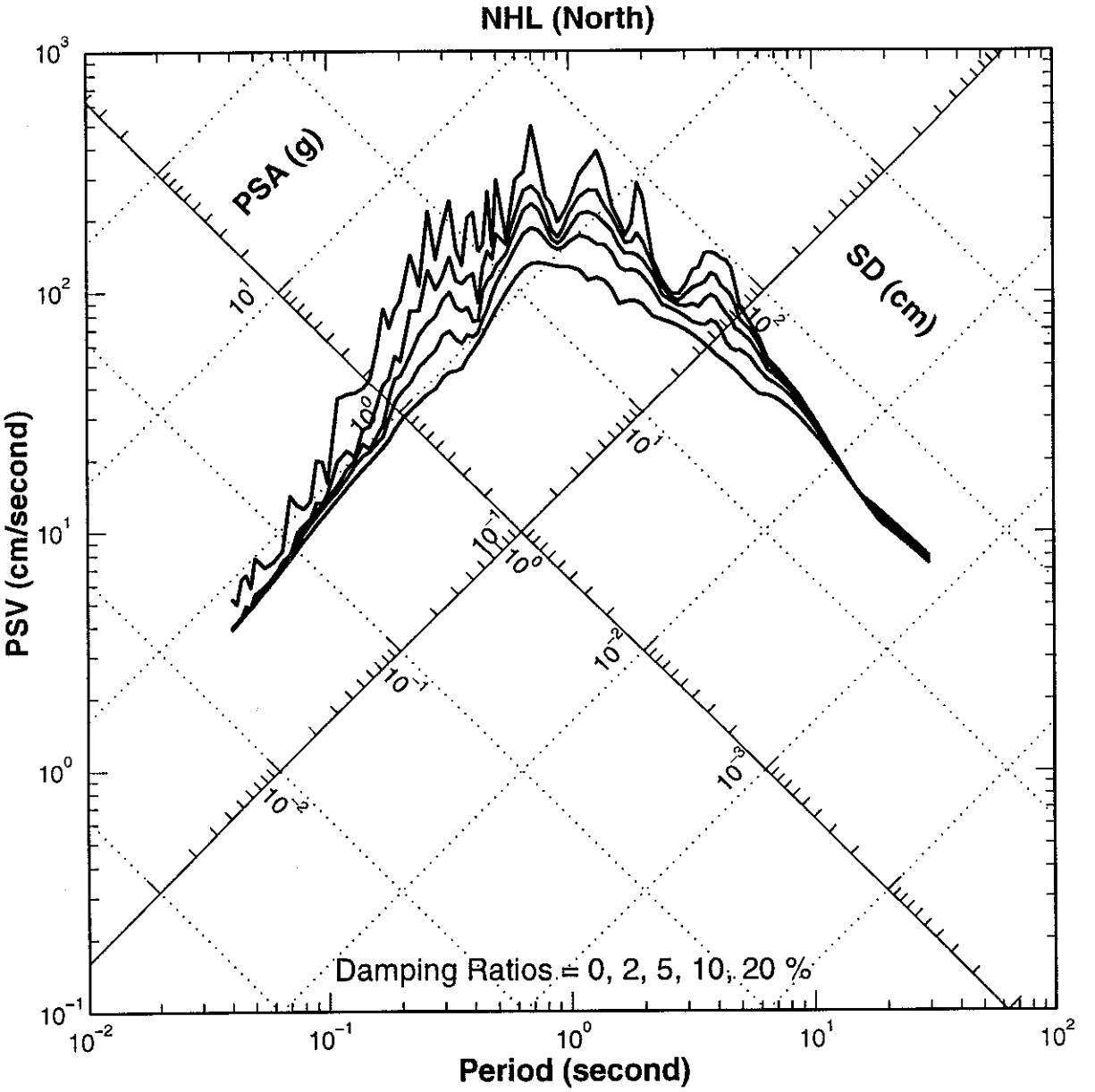
NEWHALL, LA COUNTY FIRE STATION (NHL)

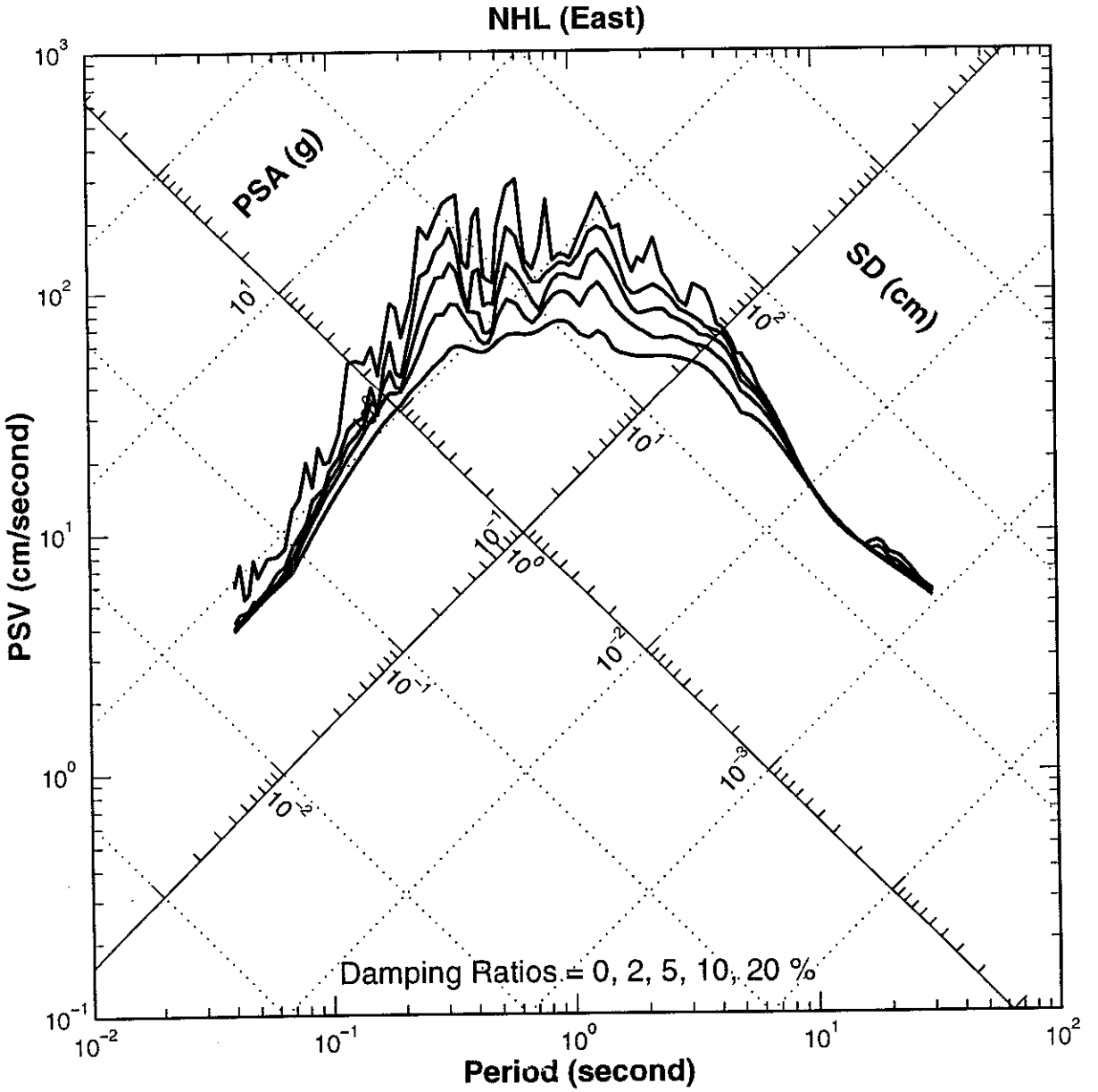

NHL (North)
Max = 581 cm/s/s
Acceleration (cm/s/s)
1000
500
0
−500
−1000
0
5
10
15
20
25
30
Max = −98 cm/s
Velocity (cm/s)
100
50
0
−50
−100
Max = 39 cm
Displacemnt (cm)
40
20
0
−20
−40
Time (second)

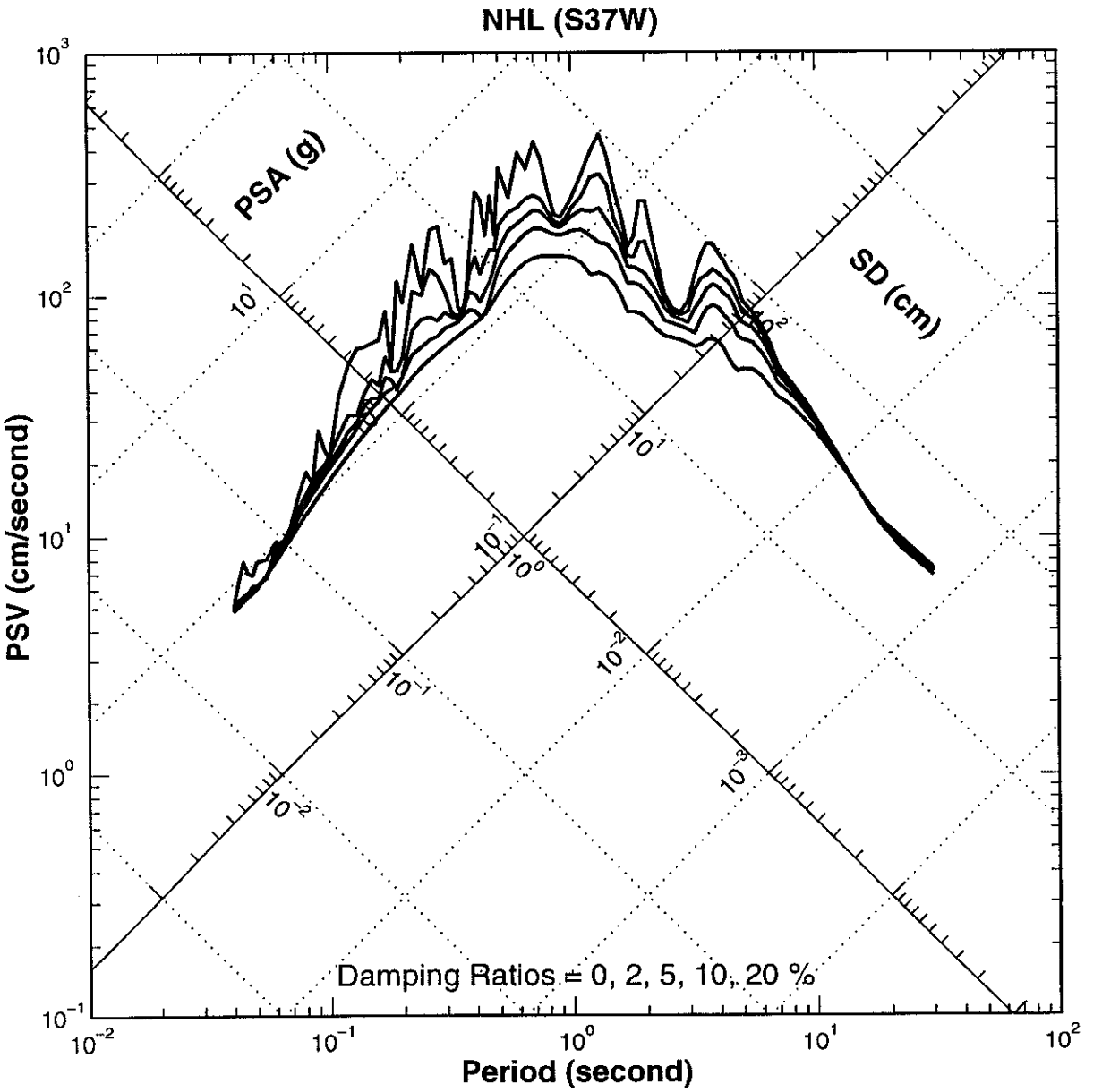

NHL (East)
Acceleration (cm/s/s)
Max = −584 cm/s/s
1000
500
0
−500
−1000
0
5
10
15
20
25
30
Velocity (cm/s)
Max = −75 cm/s
100
50
0
−50
−100
Displacemnt (cm)
Max = 22 cm
30
20
10
0
−10
−20
Time (second)

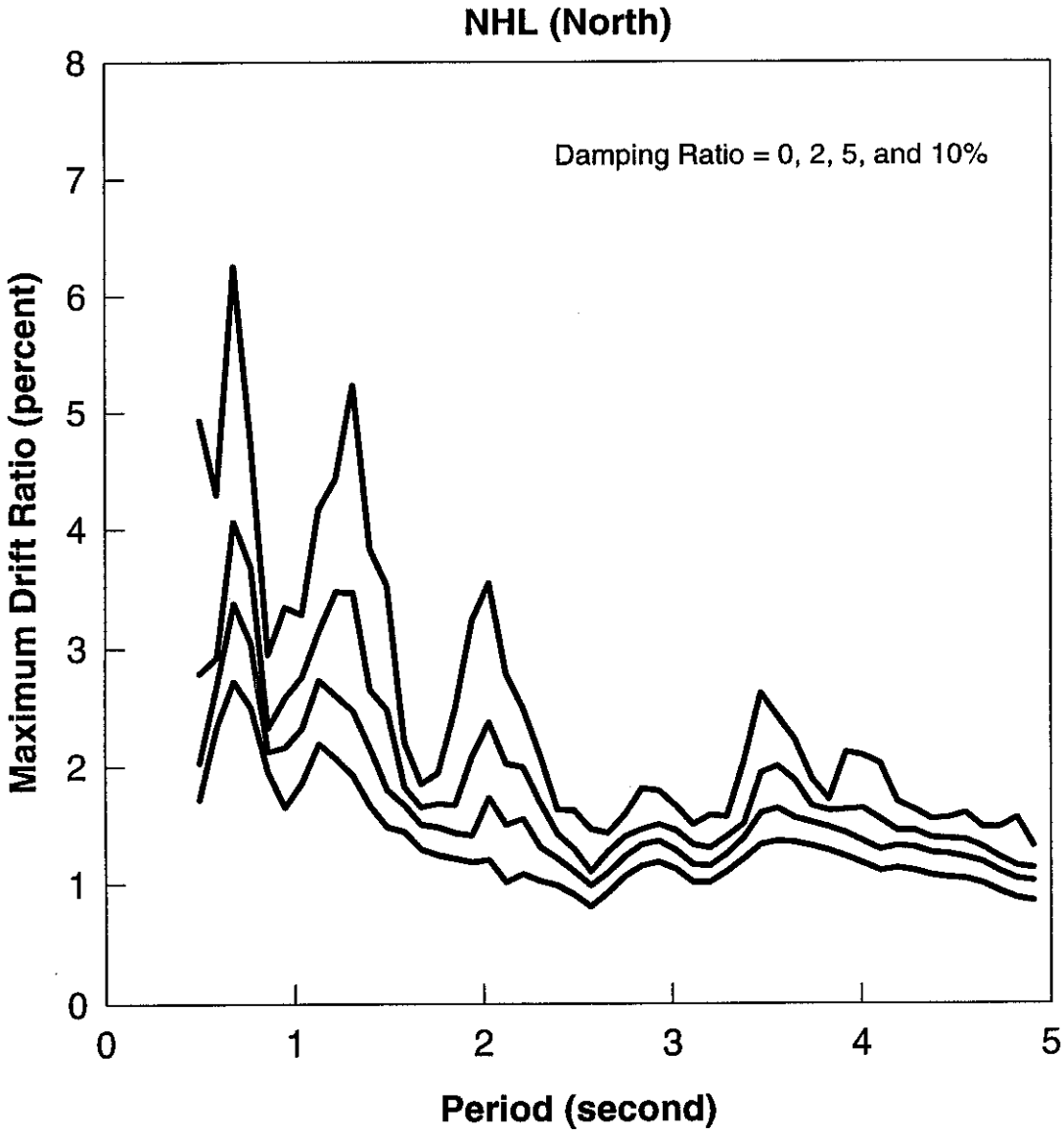

NHL (S37W)
Max = −731 cm/s/s
Acceleration (cm/s/s)
1000
500
0
−500
−1000
Max = 121 cm/s
Velocity (cm/s)
150
100
50
0
−50
−100
Max = −34 cm
Displacemnt (cm)
40
20
0
−20
−40
0
5
10
15
20
25
30
Time (second)

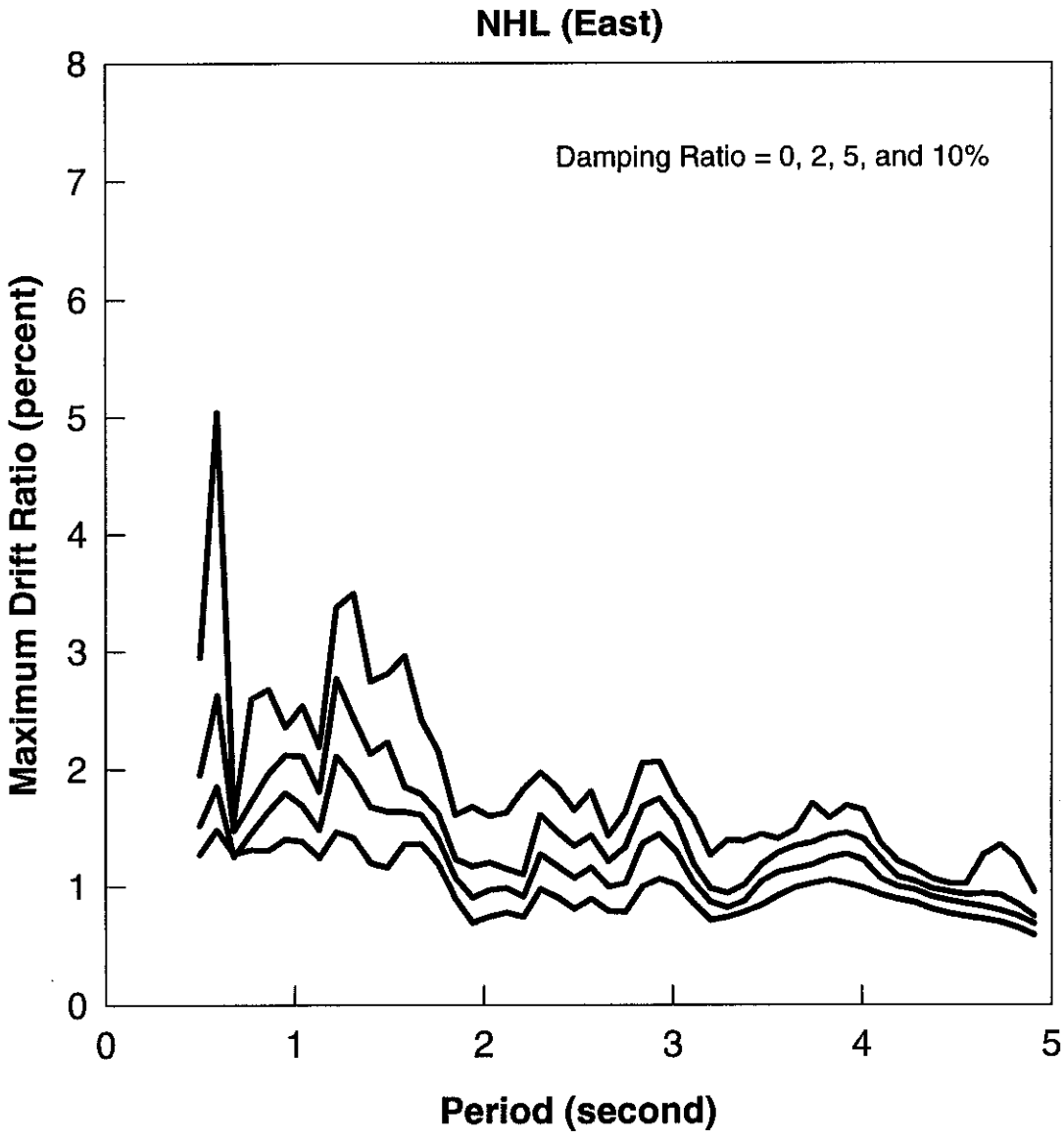

NHL Particle Trajectory
North (cm)
East (cm)
40
30
20
10
0
−10
−20
−30
−30
−20
−10
0
10
20
30
40

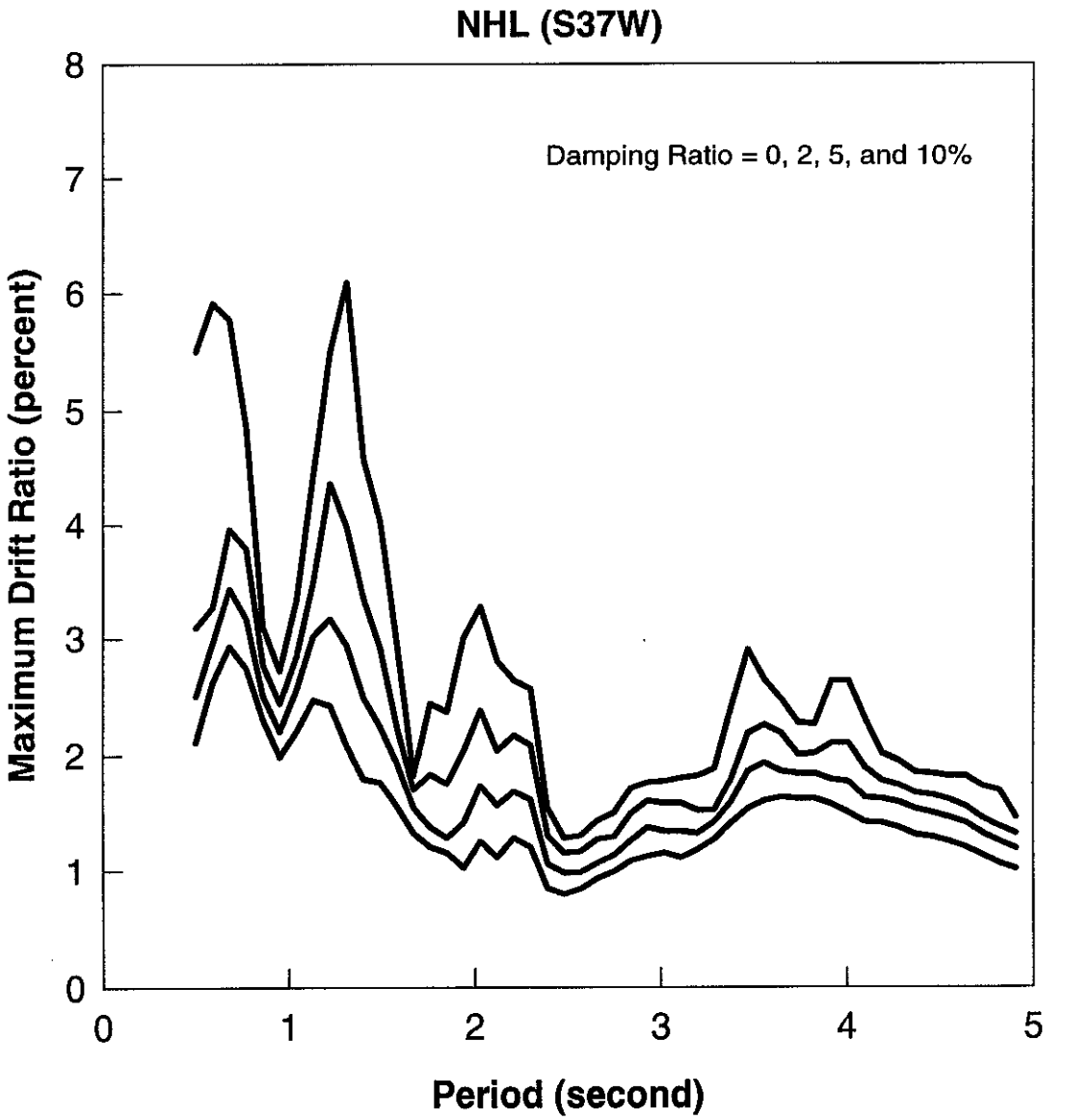

NHL (North)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %


NHL (East)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %

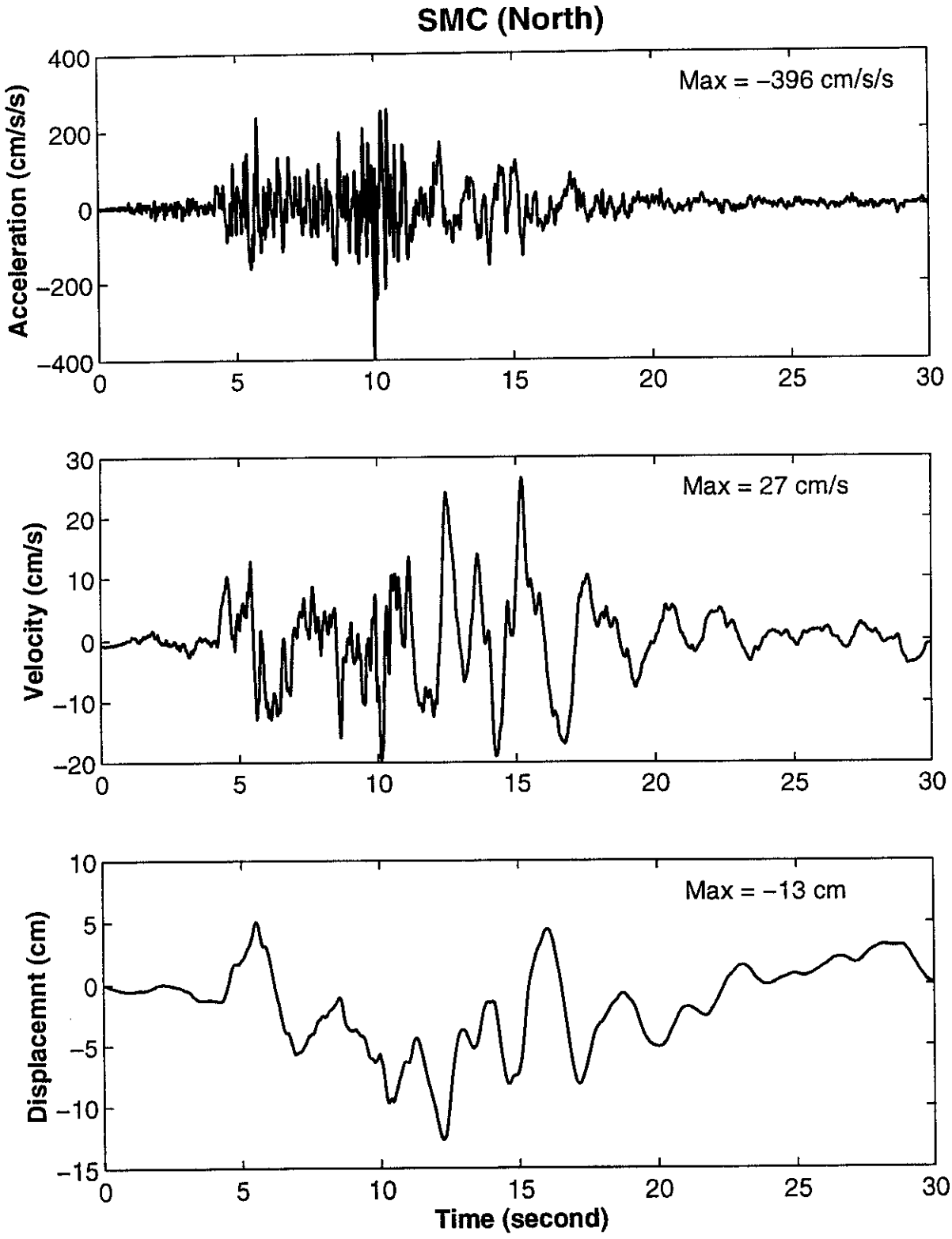

NHL (S37W)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %

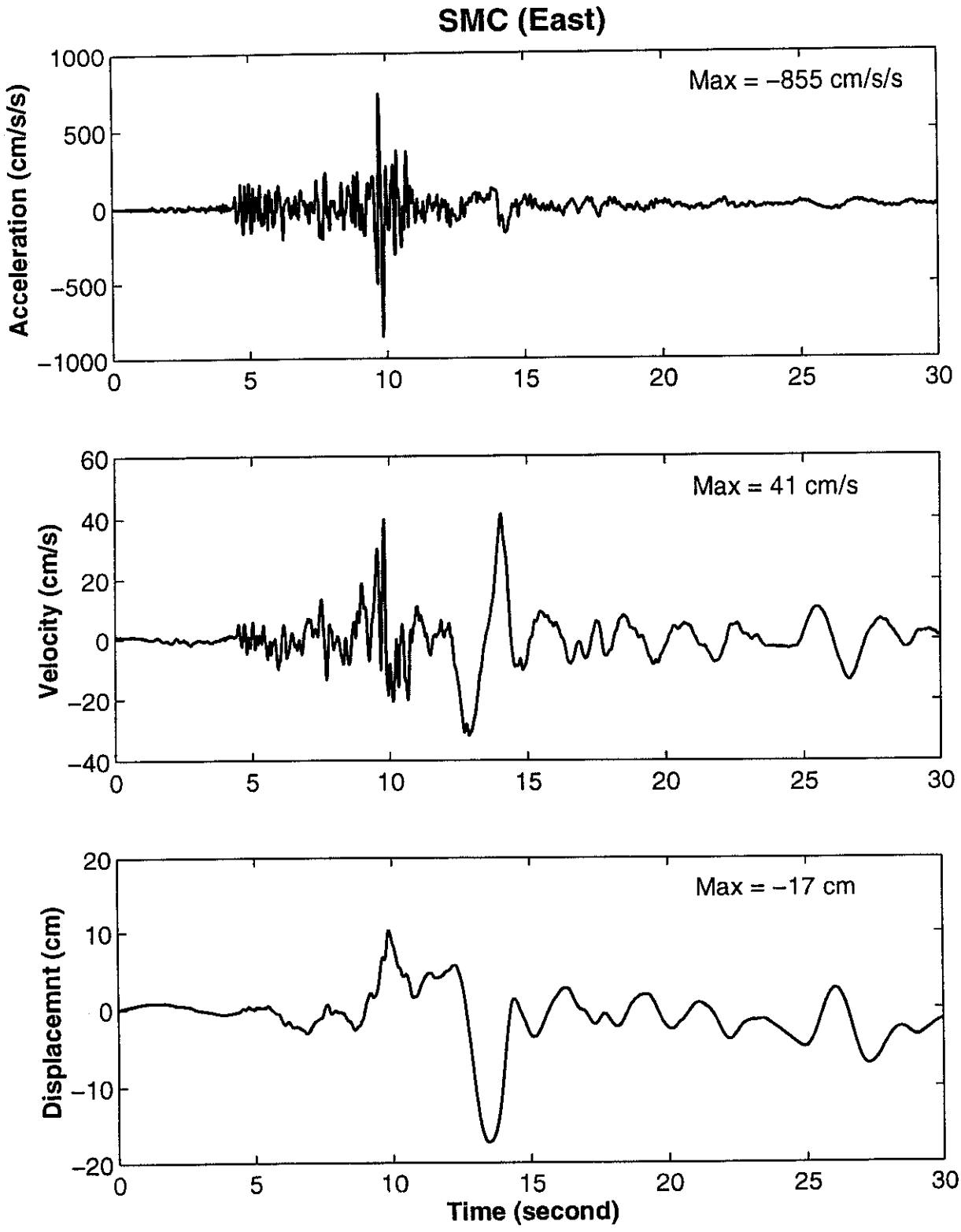

NHL (North)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5

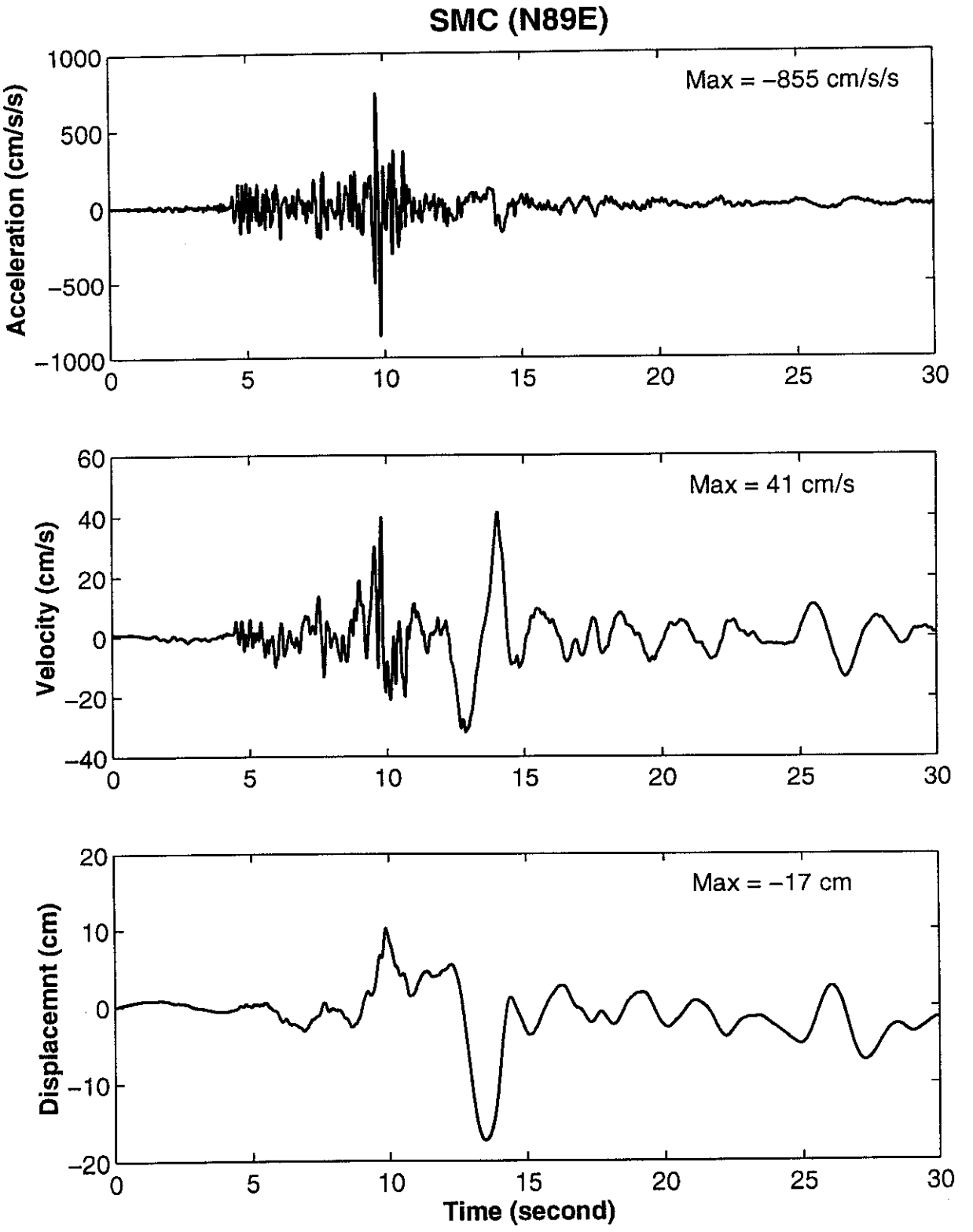

NHL (East)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5

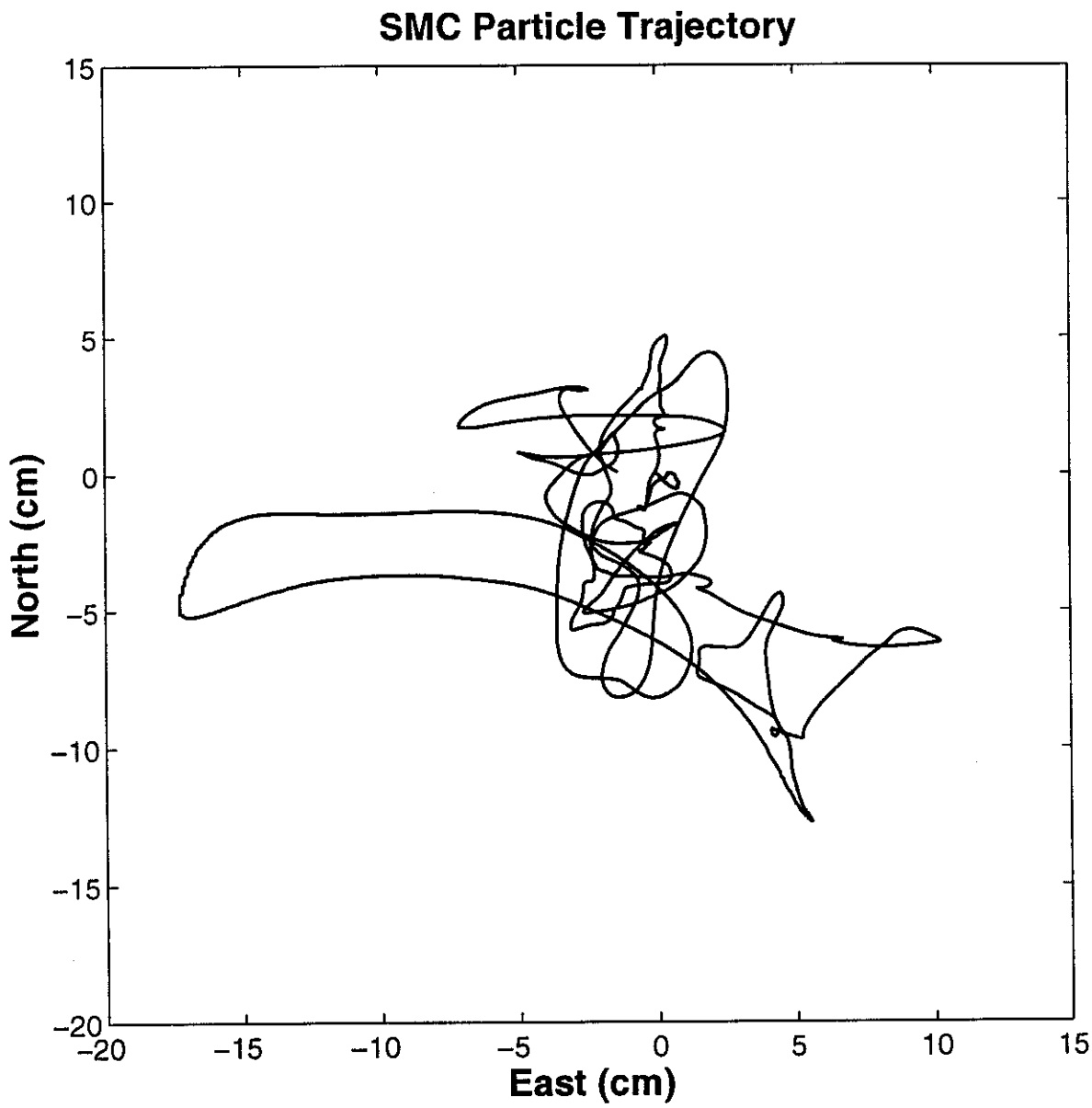

NHL (S37W)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5

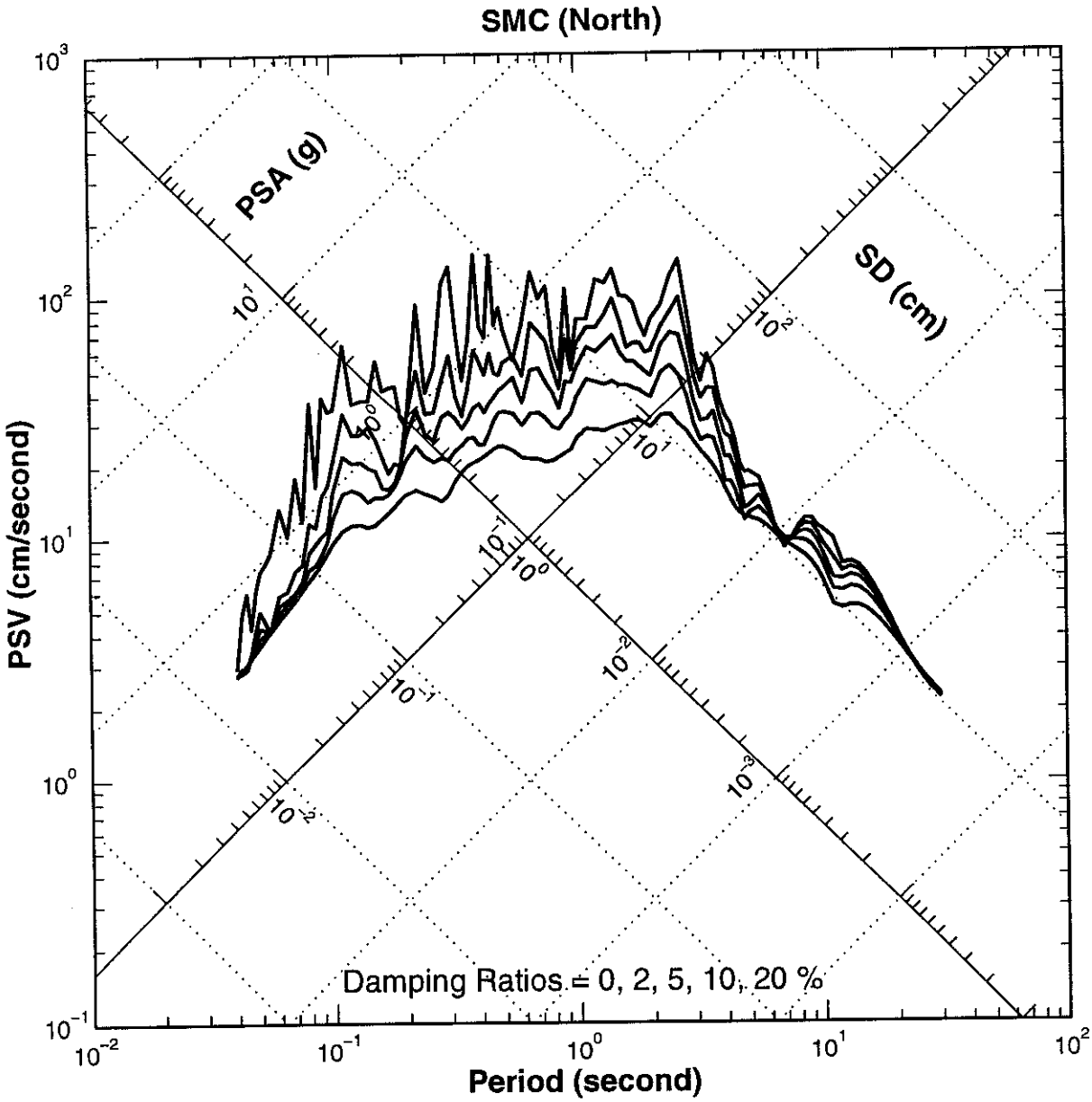
SANTA MONICA CITY HALL GROUNDS (SMC)

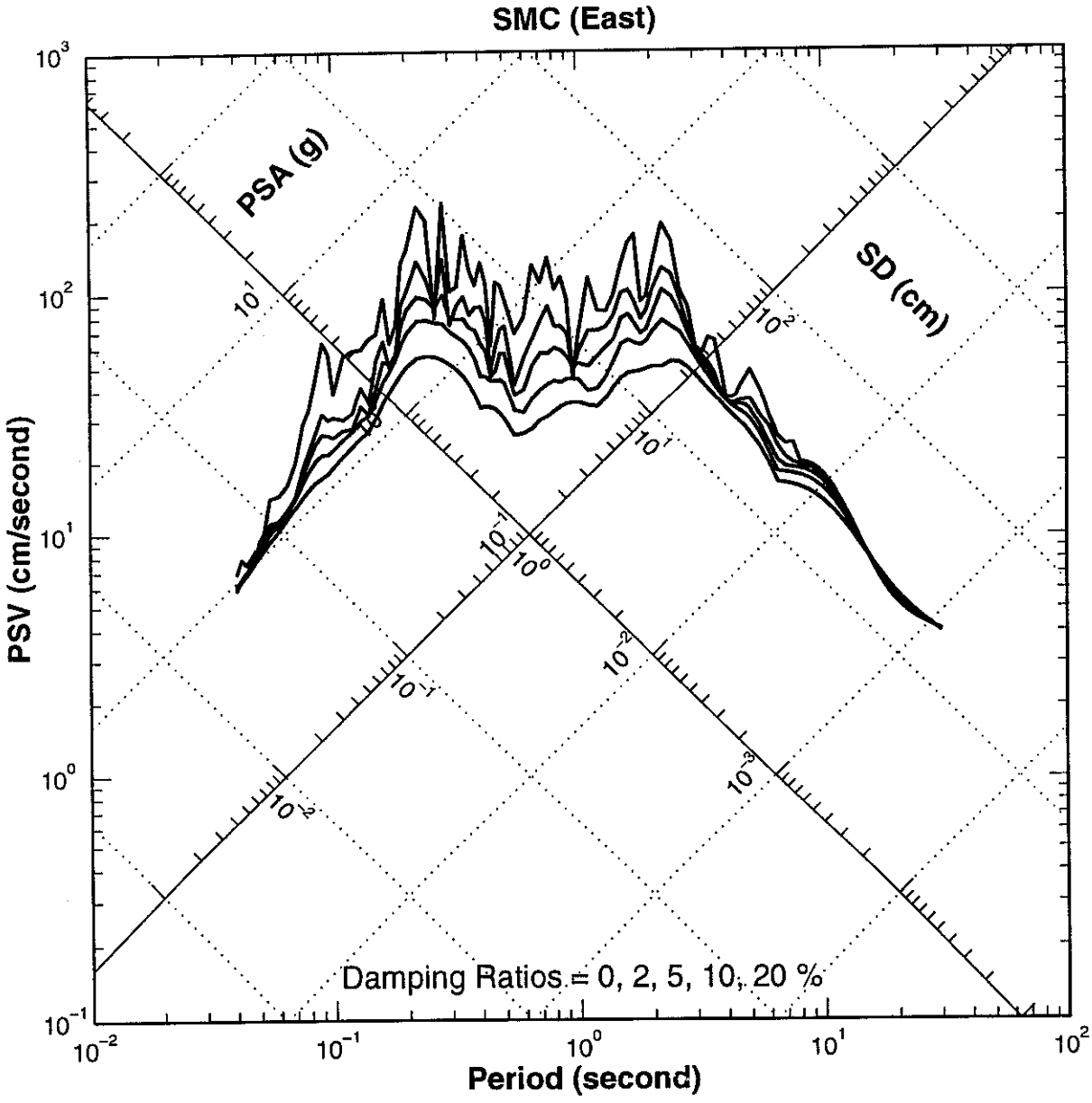

SMC (North)
Max = −396 cm/s/s
Acceleration (cm/s/s)
400
200
0
−200
−400
0
5
10
15
20
25
30
Max = 27 cm/s
Velocity (cm/s)
30
20
10
0
−10
−20
Max = −13 cm
Displacemnt (cm)
10
5
0
−5
−10
−15
Time (second)

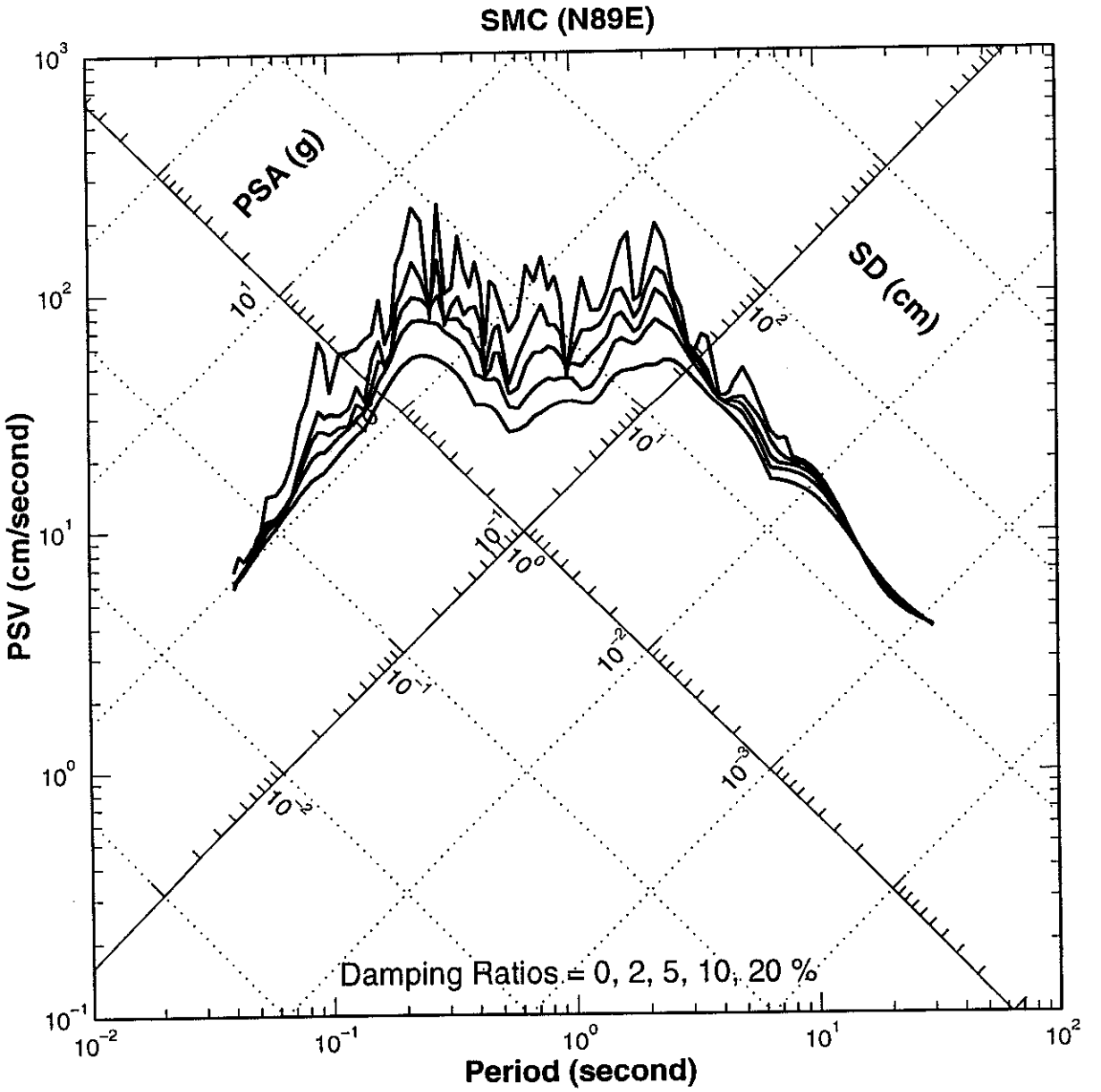

SMC (East)
Max = −855 cm/s/s
Acceleration (cm/s/s)
1000
500
0
−500
−1000
0
5
10
15
20
25
30
Max = 41 cm/s
Velocity (cm/s)
60
40
20
0
−20
−40
Max = −17 cm
Displacemnt (cm)
20
10
0
−10
−20
Time (second)

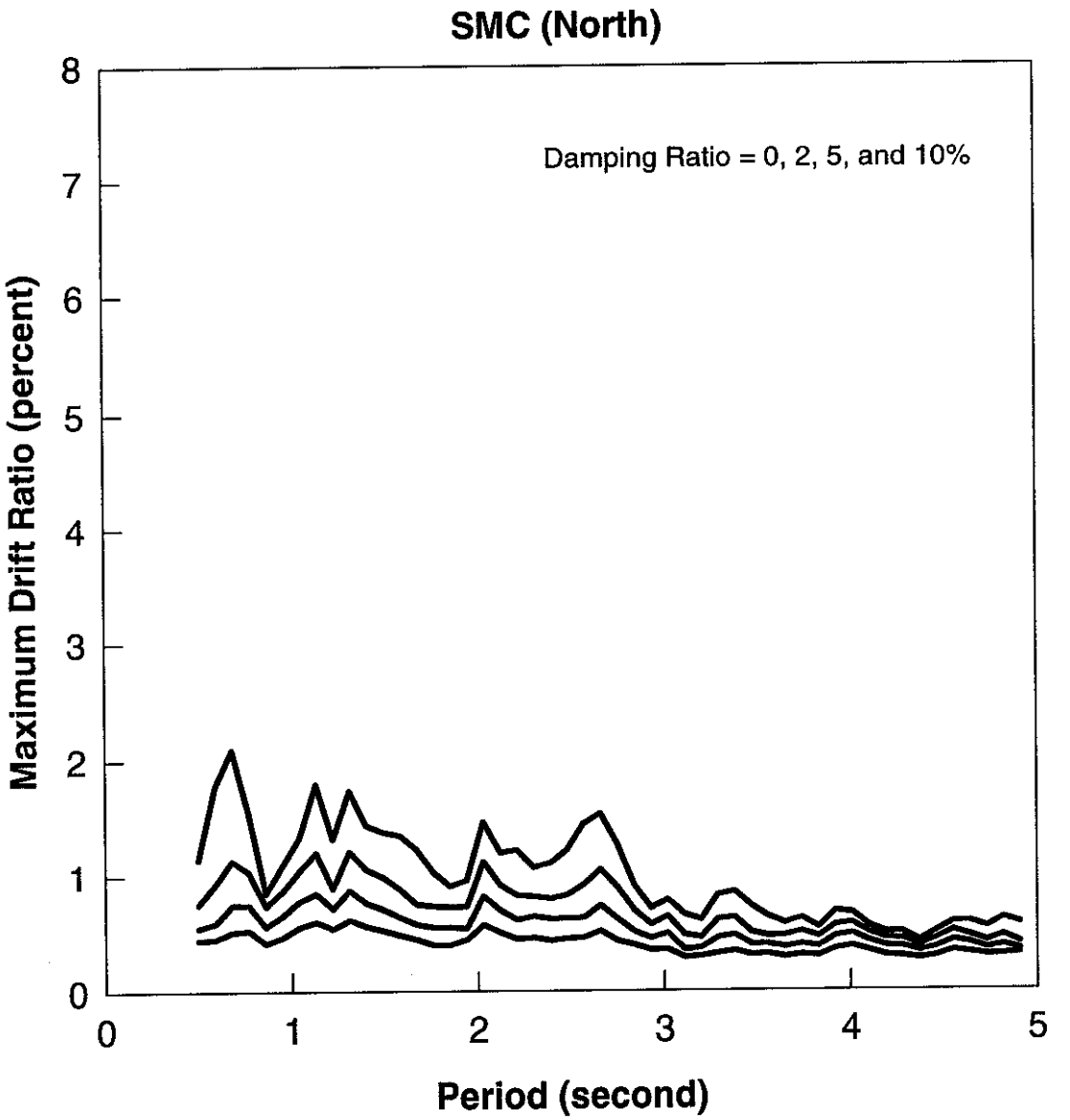

SMC (N89E)
Acceleration (cm/s/s)
Max = −855 cm/s/s
1000
500
0
−500
−1000
0
5
10
15
20
25
30
Velocity (cm/s)
Max = 41 cm/s
60
40
20
0
−20
−40
Displacemnt (cm)
Max = −17 cm
20
10
0
−10
−20
Time (second)

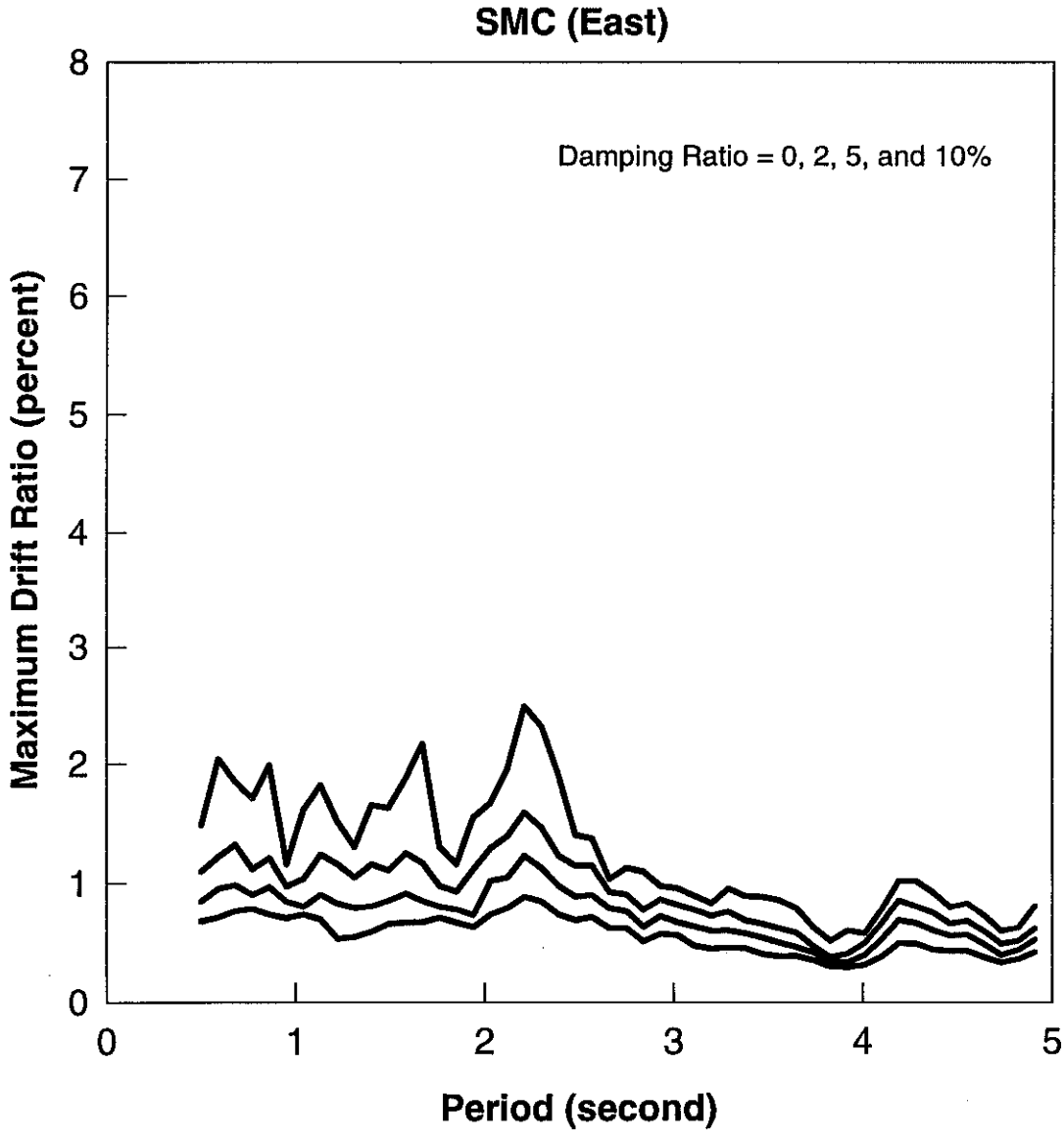

SMC Particle Trajectory
North (cm)
East (cm)
15
10
5
0
−5
−10
−15
−20
−20
−15
−10
−5
0
5
10
15

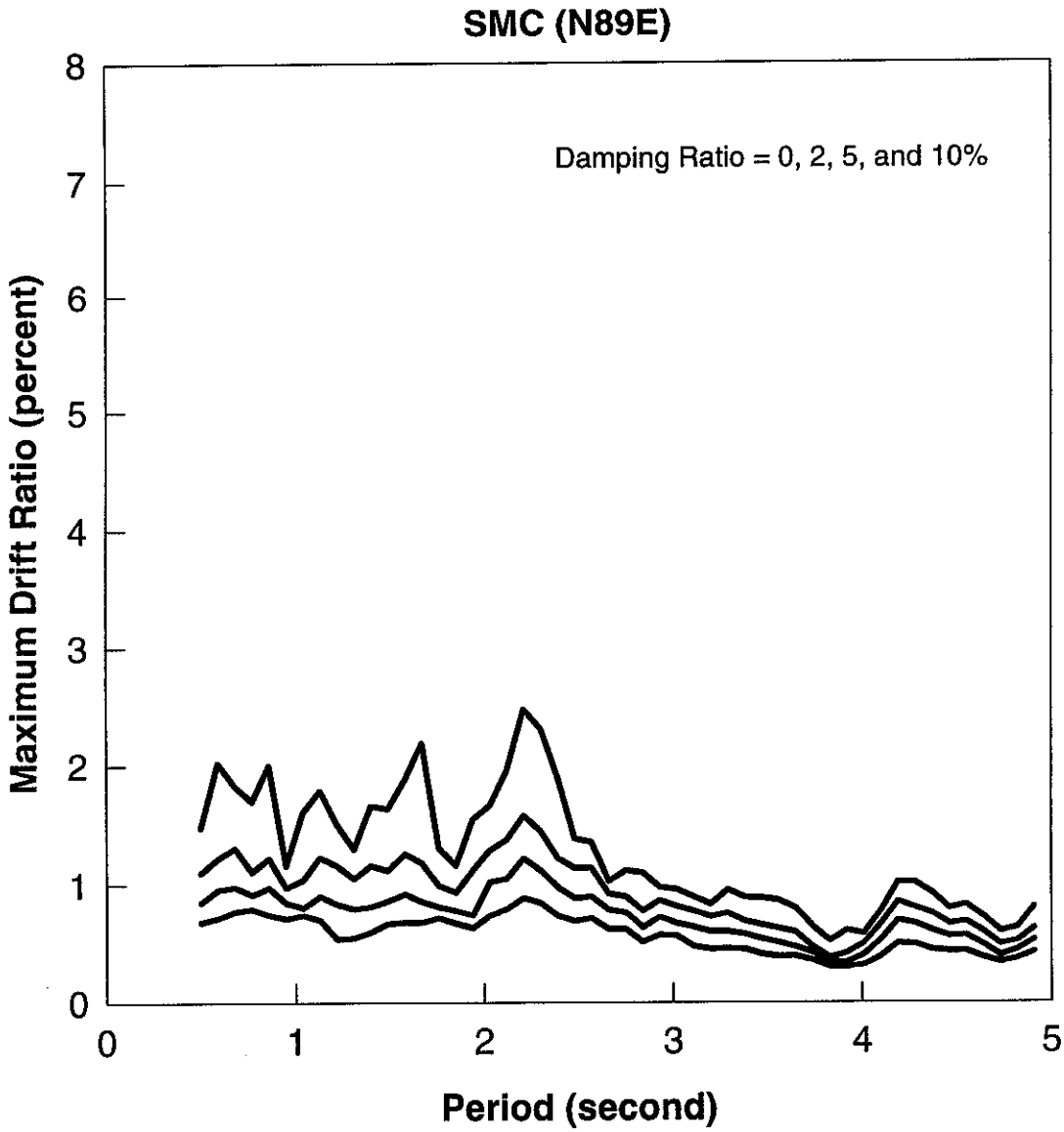

SMC (North)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %


SMC (East)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %

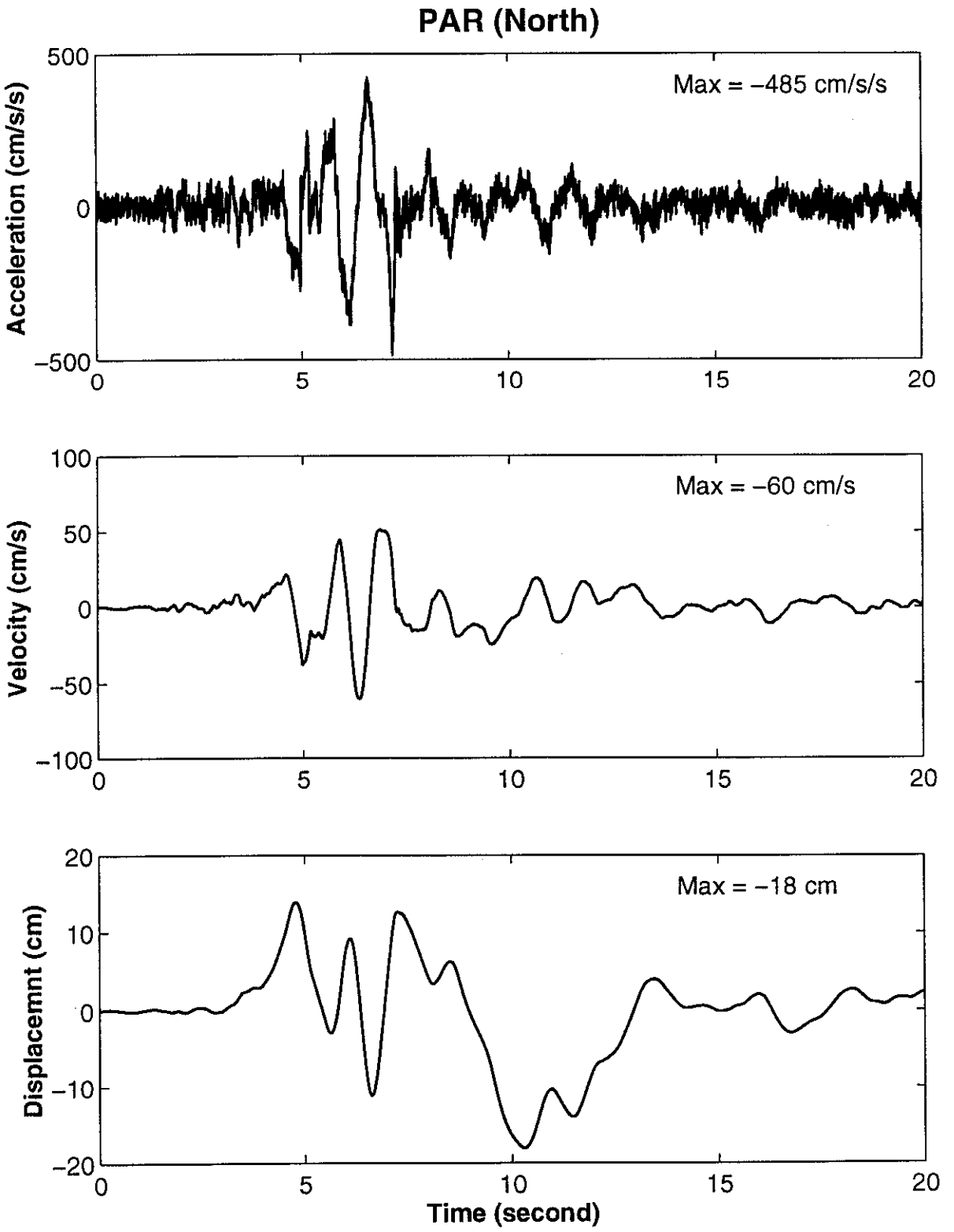

SMC (N89E)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %

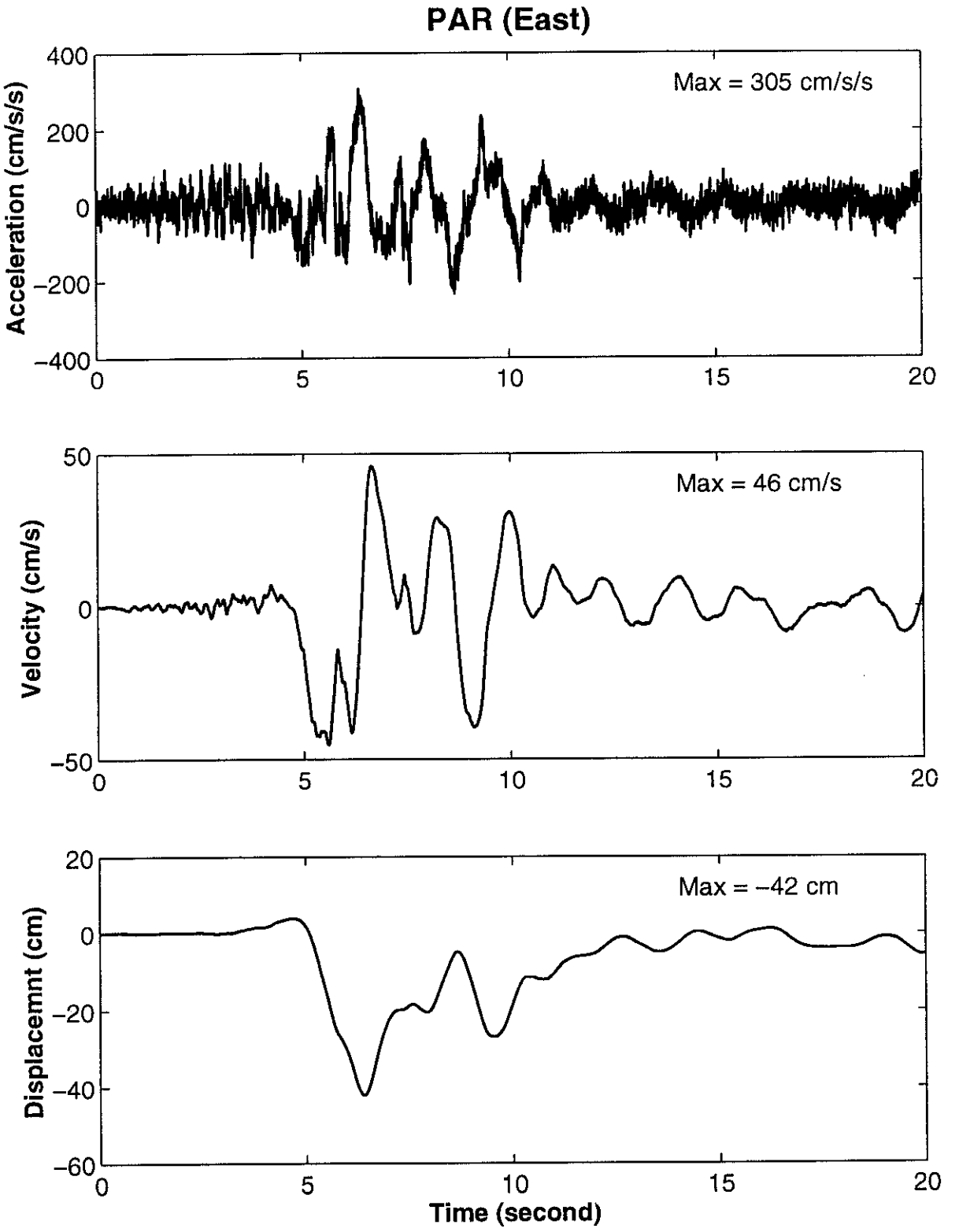

SMC (North)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5

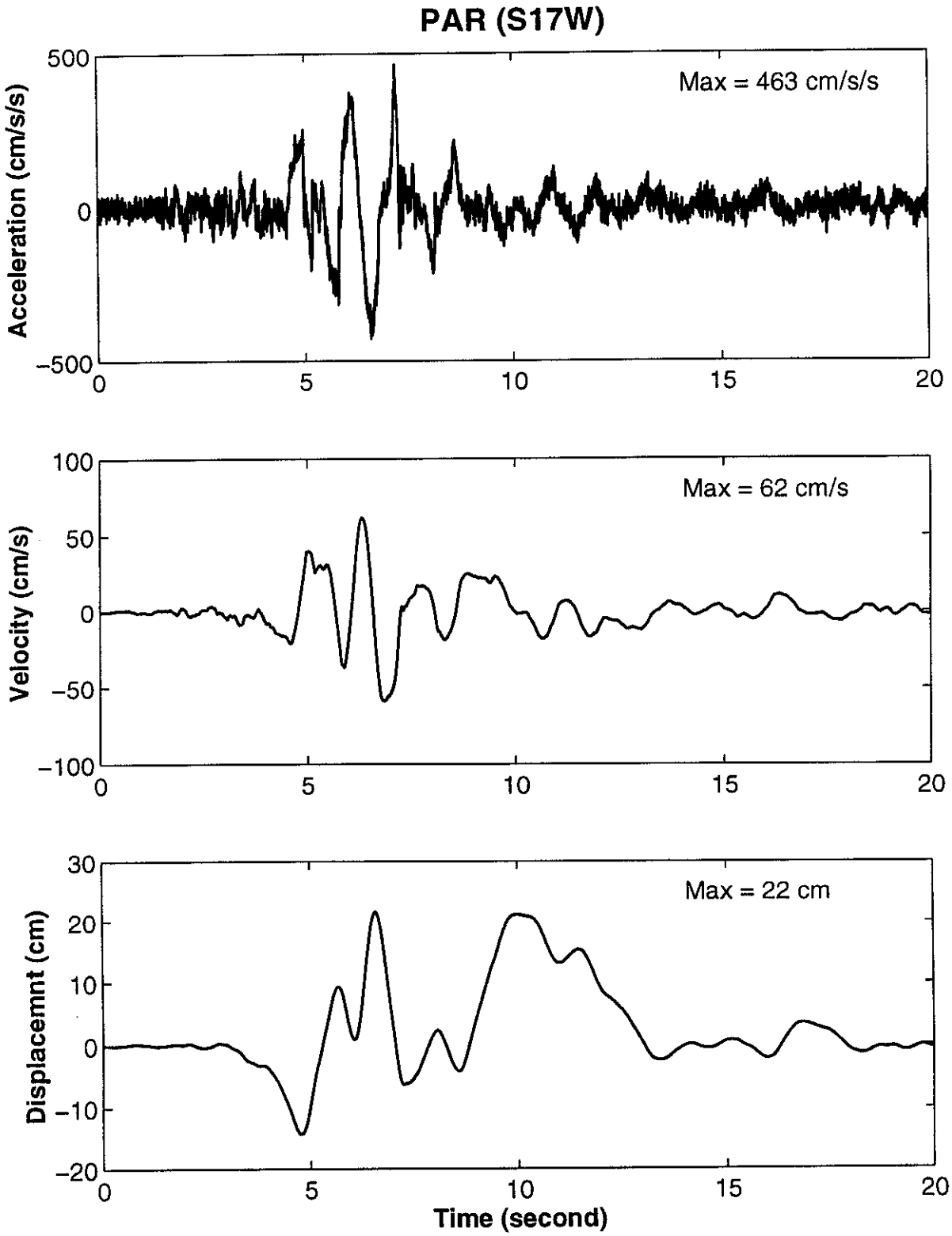

SMC (East)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5
Period (second)

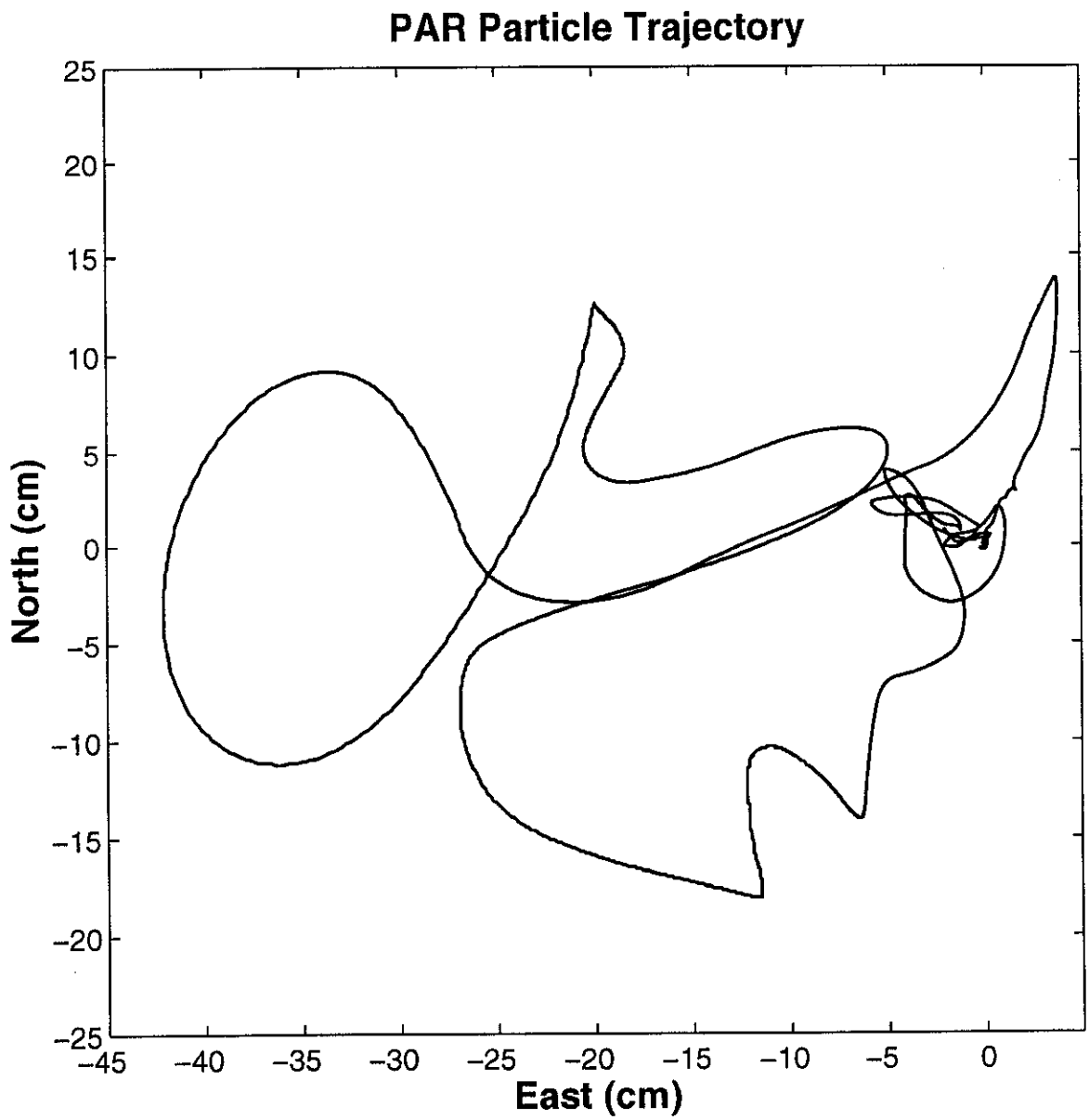

SMC (N89E)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5

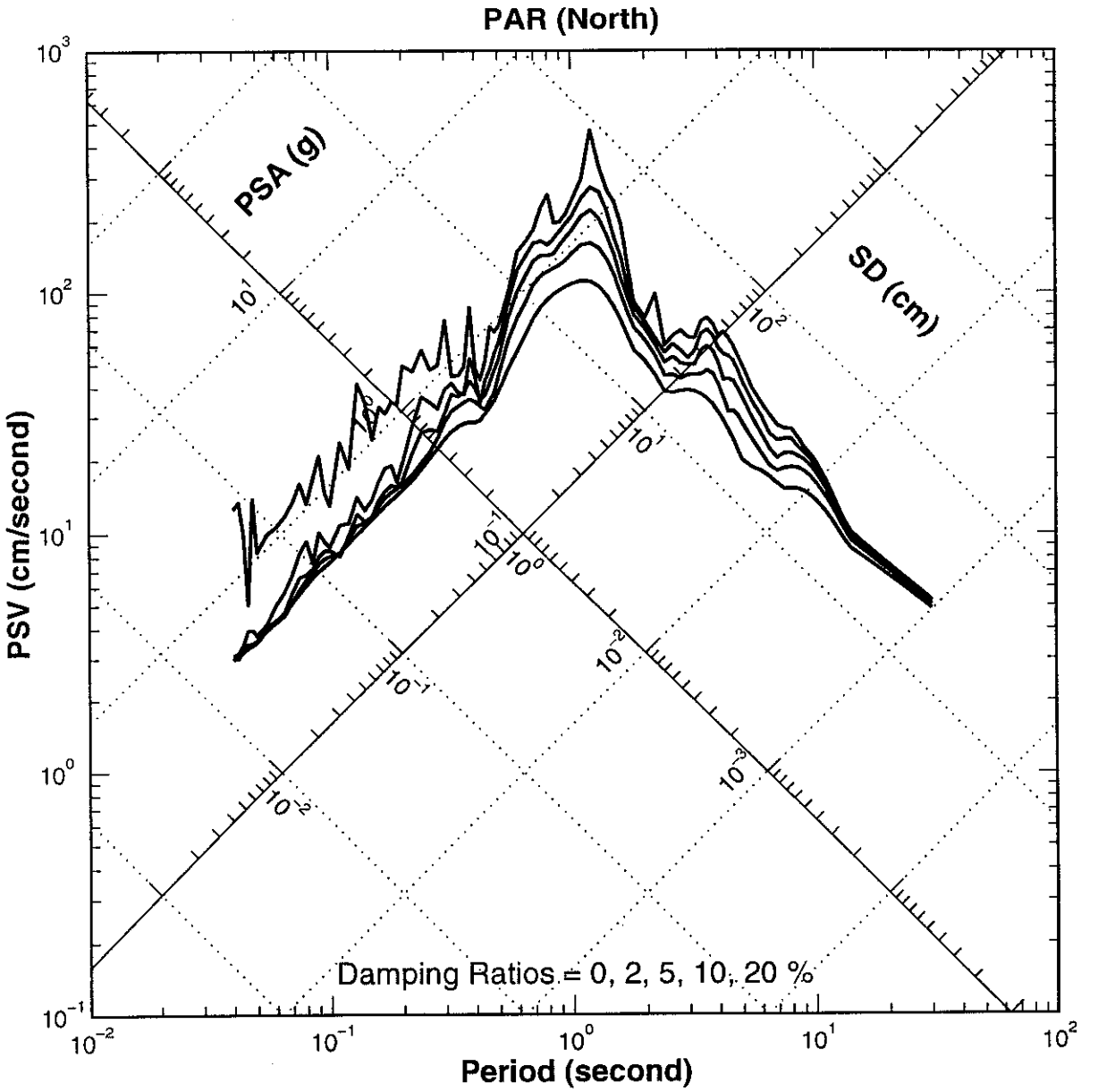
PARDEE STATION (PAR)

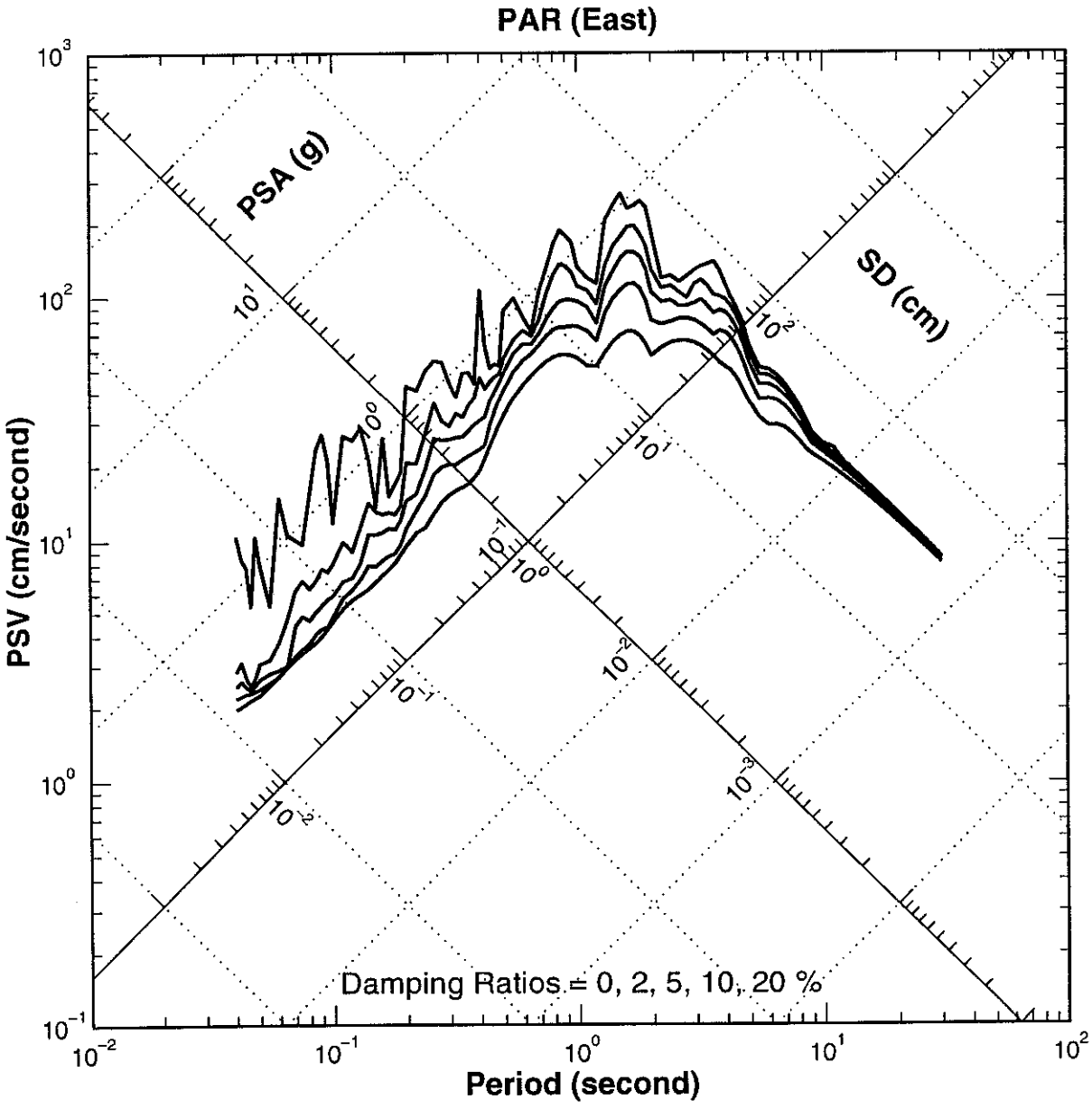

PAR (North)
Max = −485 cm/s/s
Acceleration (cm/s/s)
500
0
−500
0
5
10
15
20
Max = −60 cm/s
Velocity (cm/s)
100
50
0
−50
−100
Max = −18 cm
Displacemnt (cm)
20
10
0
−10
−20
Time (second)

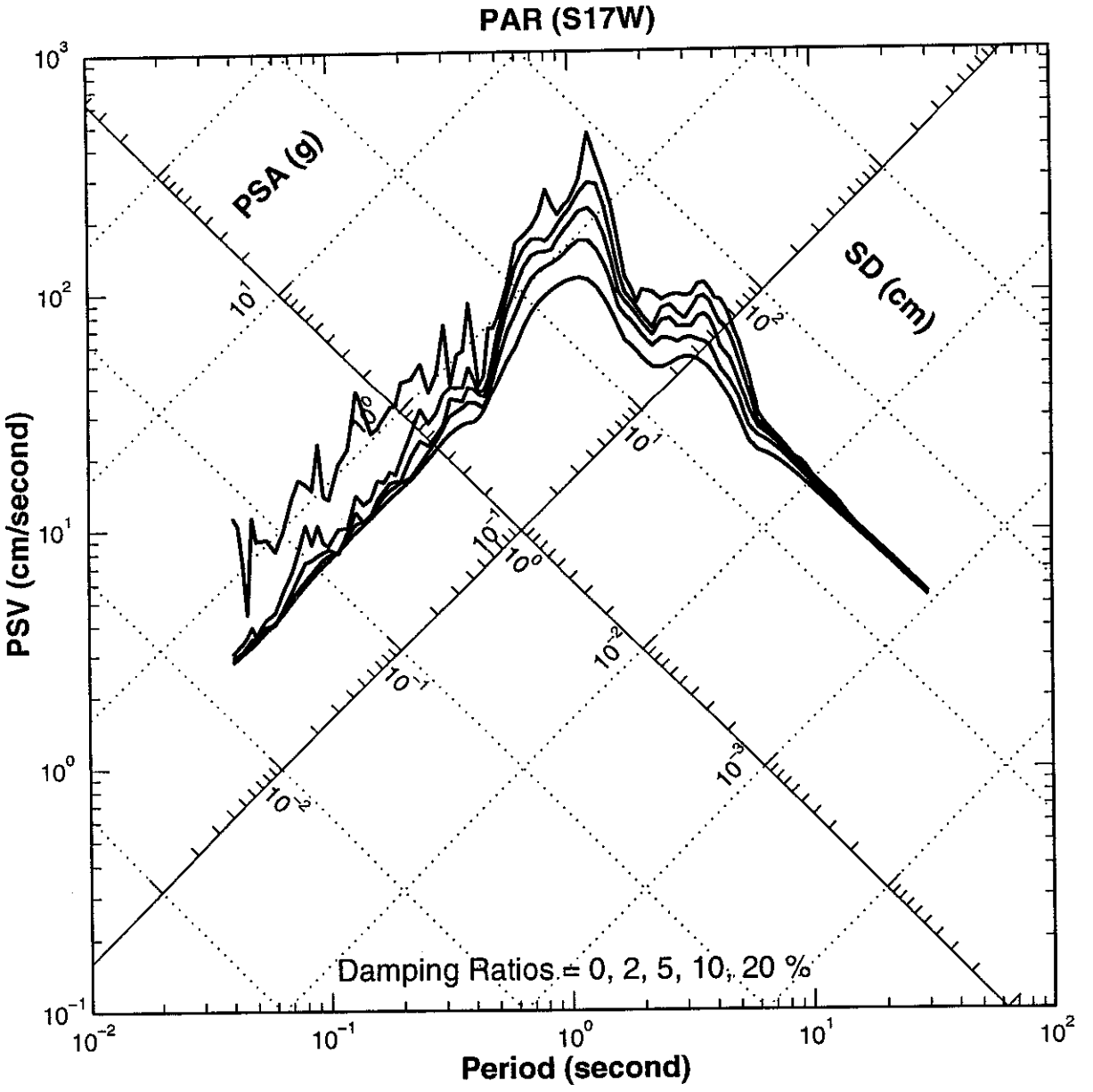

PAR (East)
Max = 305 cm/s/s
Acceleration (cm/s/s)
400
200
0
−200
−400
0
5
10
15
20
Max = 46 cm/s
Velocity (cm/s)
50
0
−50
Max = −42 cm
Displacemnt (cm)
20
0
−20
−40
−60
Time (second)

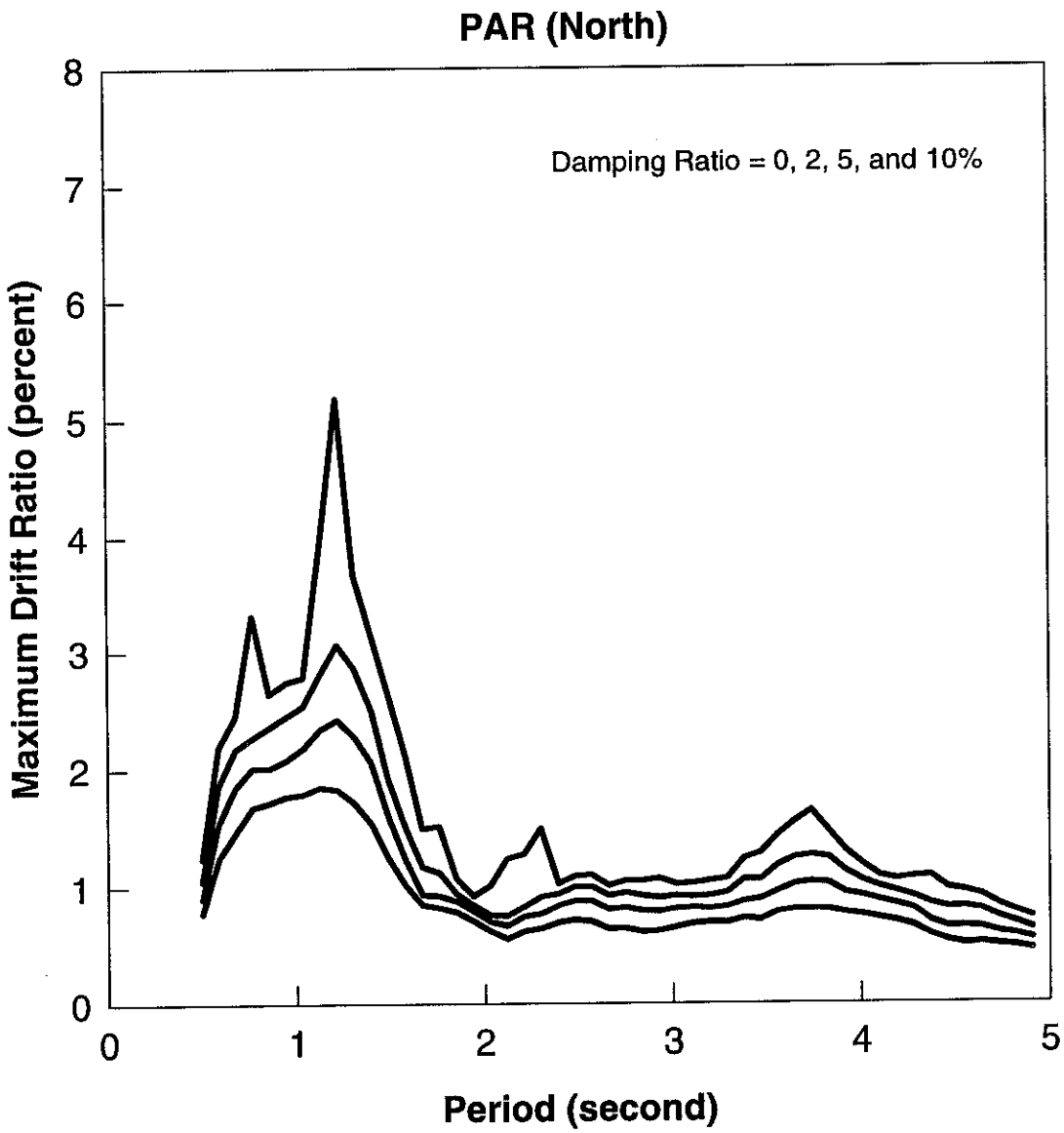

PAR (S17W)
Max = 463 cm/s/s
Acceleration (cm/s/s)
500
0
−500
0
5
10
15
20
Max = 62 cm/s
Velocity (cm/s)
100
50
0
−50
−100
Max = 22 cm
Displacemnt (cm)
30
20
10
0
−10
−20
Time (second)

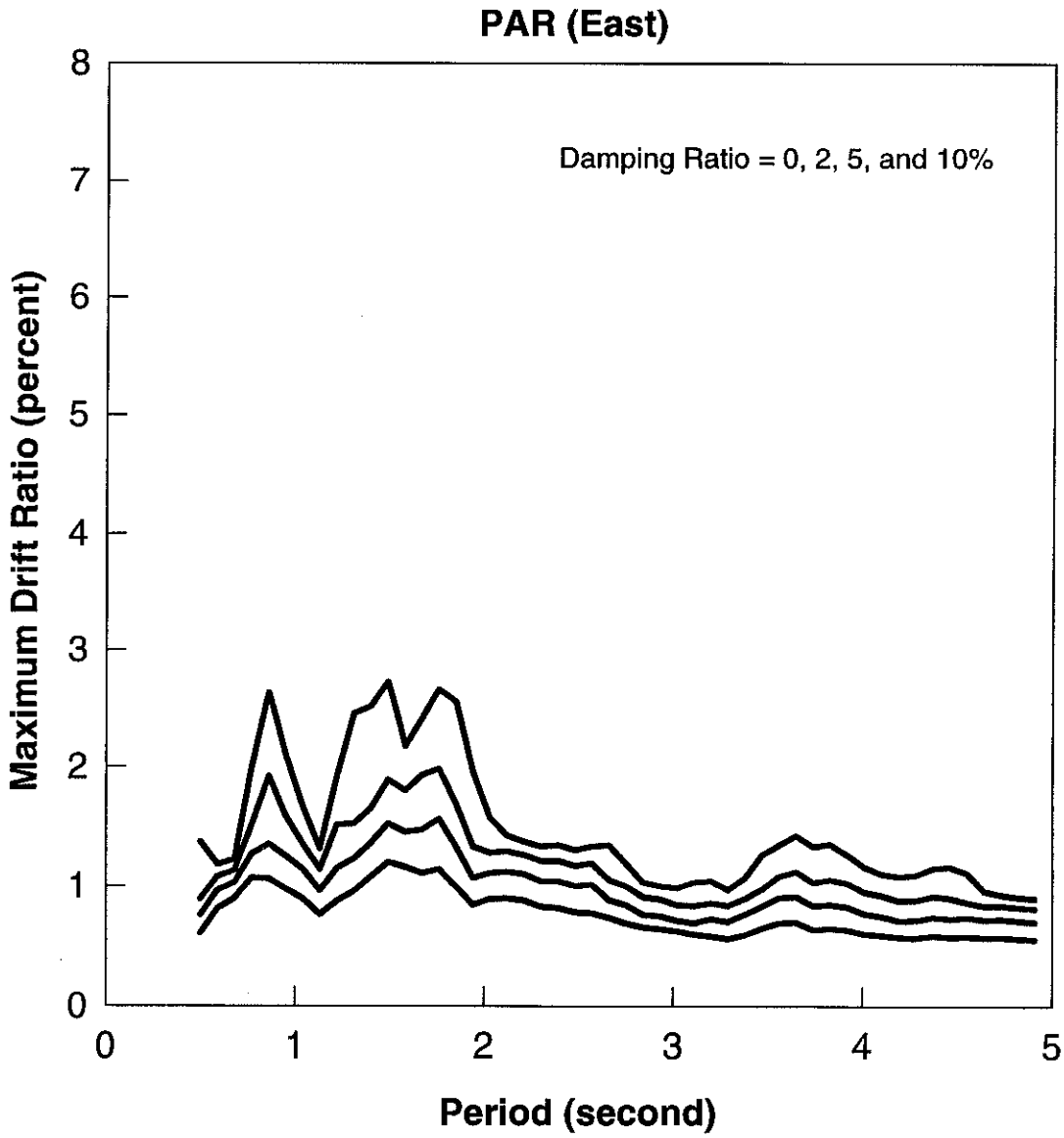

PAR Particle Trajectory
North (cm)
East (cm)
25
20
15
10
5
0
−5
−10
−15
−20
−25
−45
−40
−35
−30
−25
−20
−15
−10
−5
0

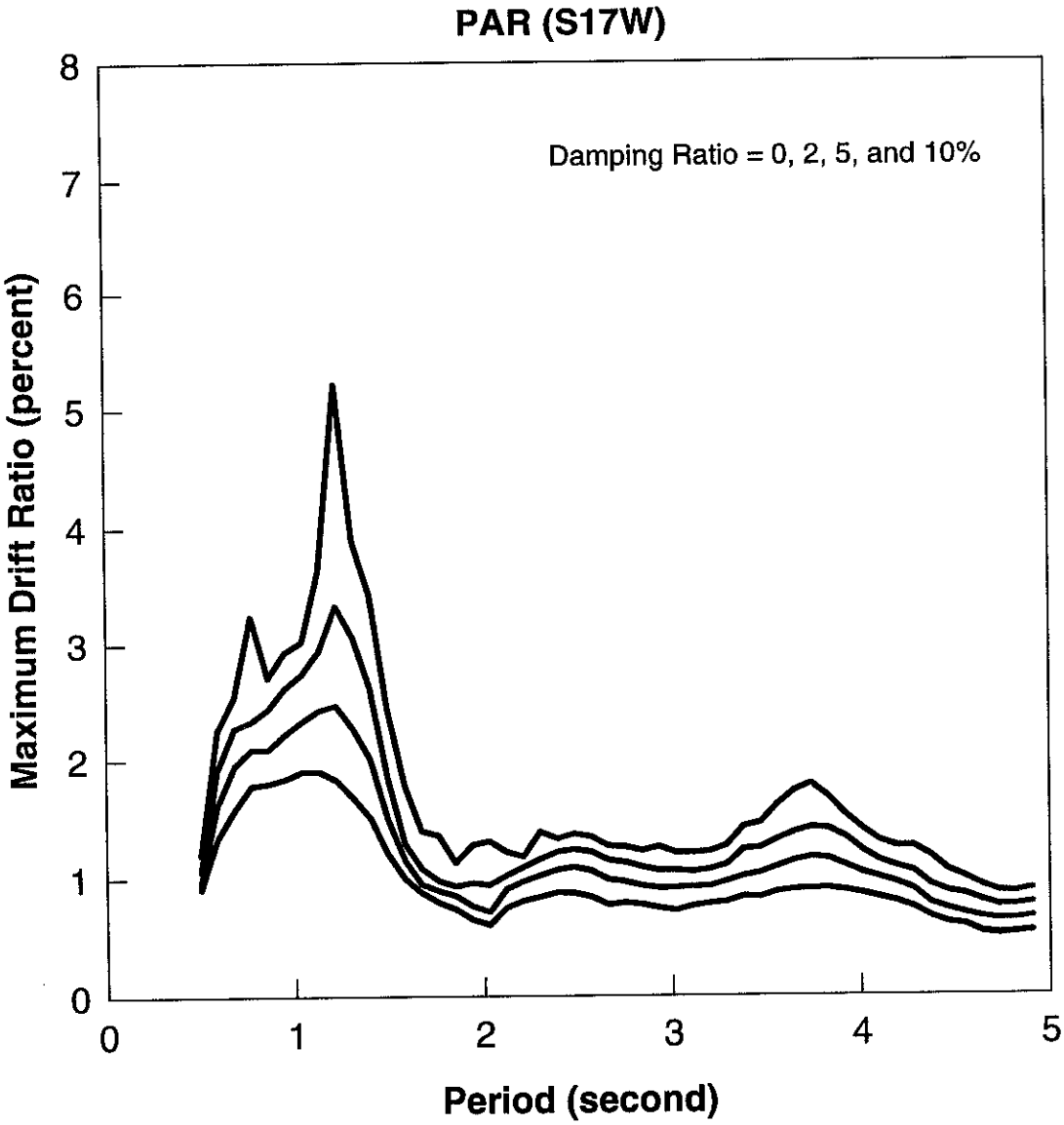

PAR (North)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %


PAR (East)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %

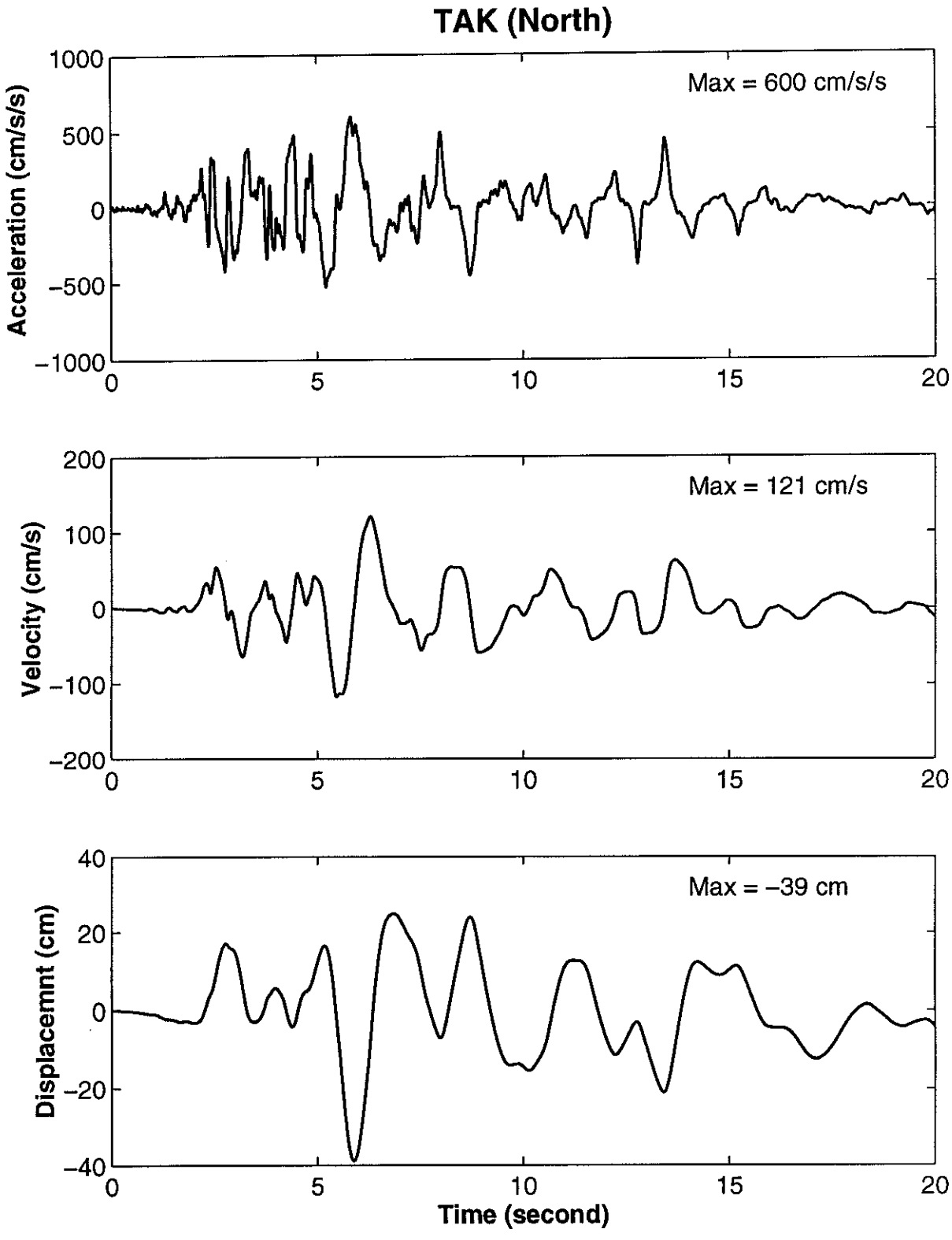

PAR (S17W)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %

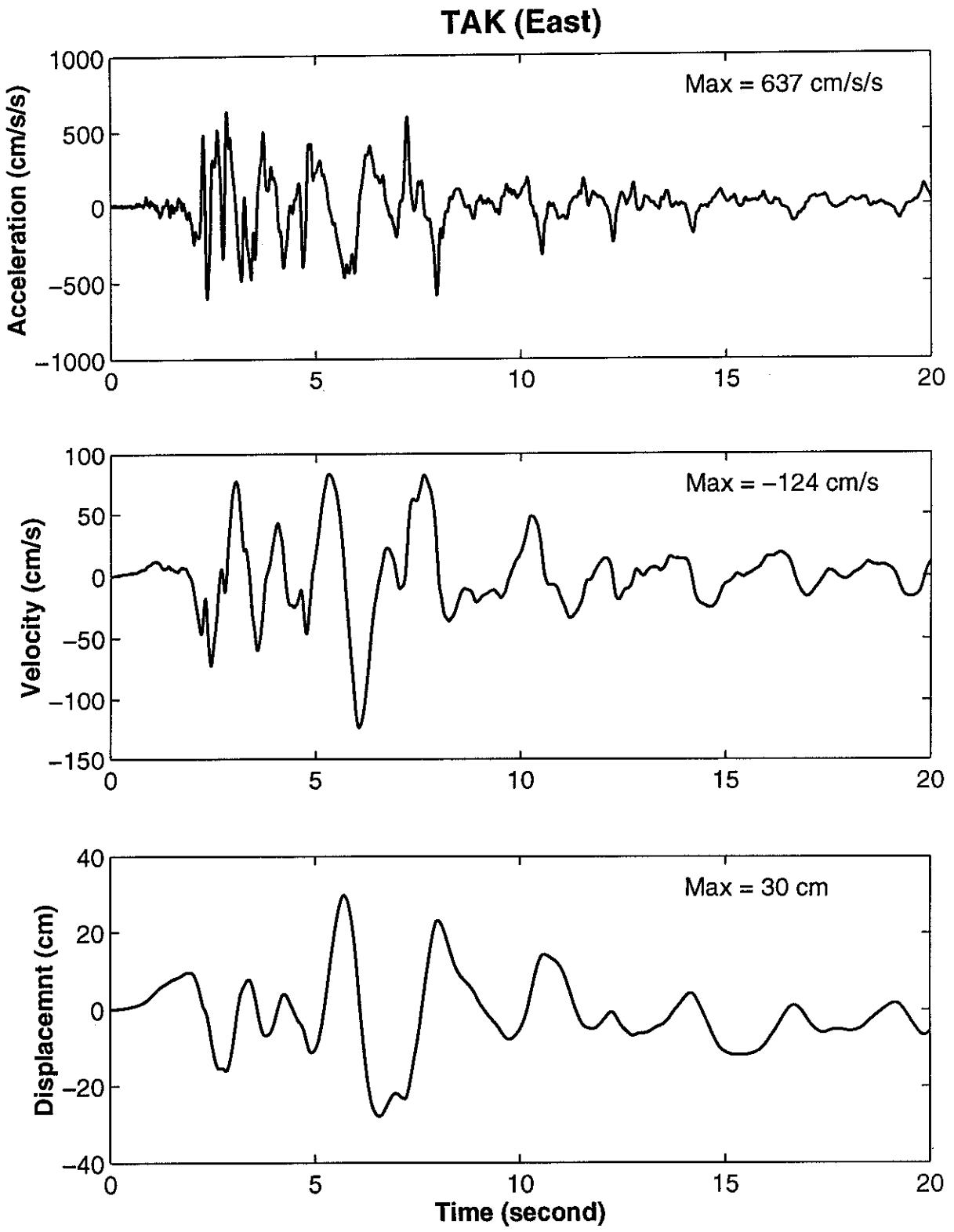

PAR (North)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5

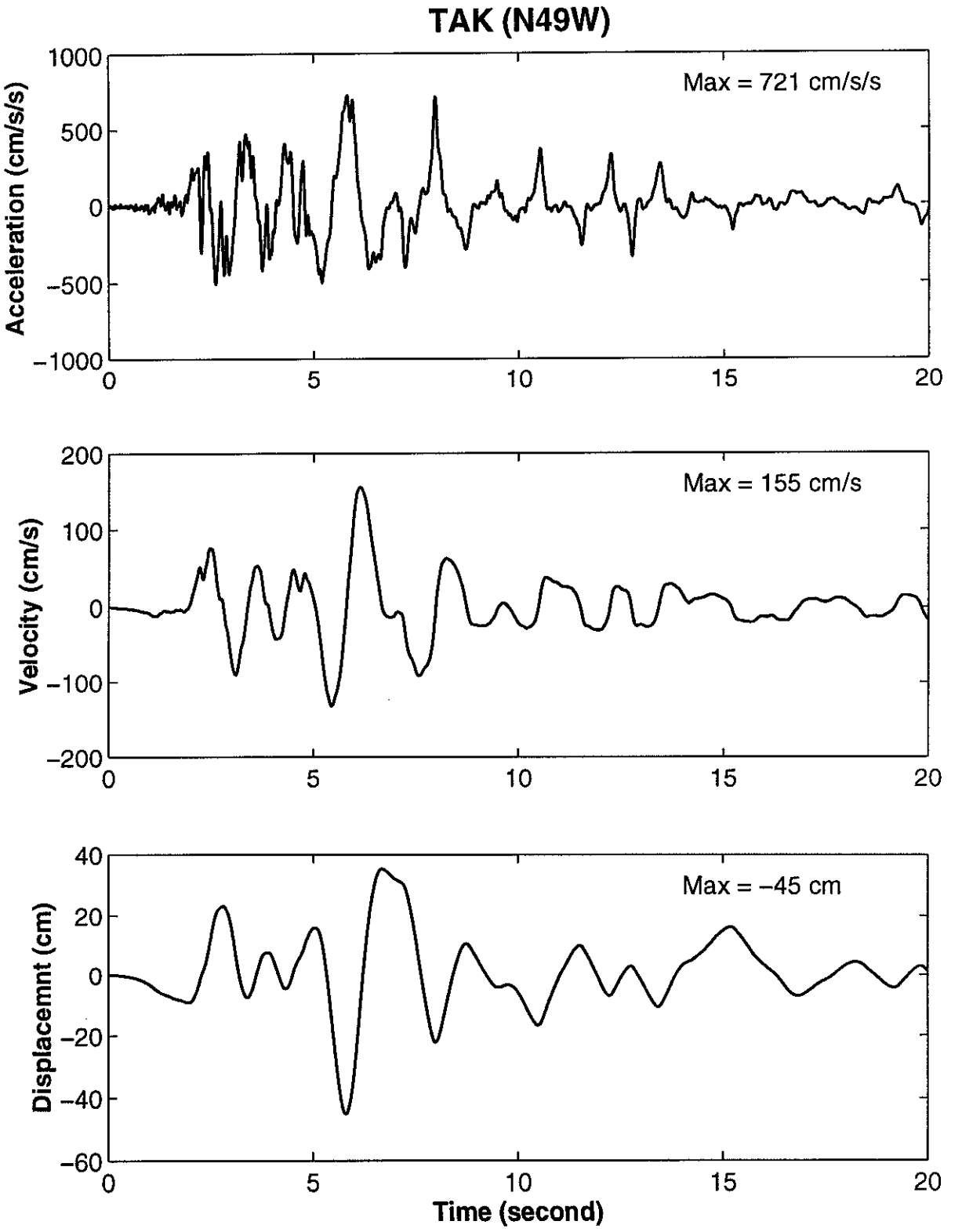

PAR (East)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5

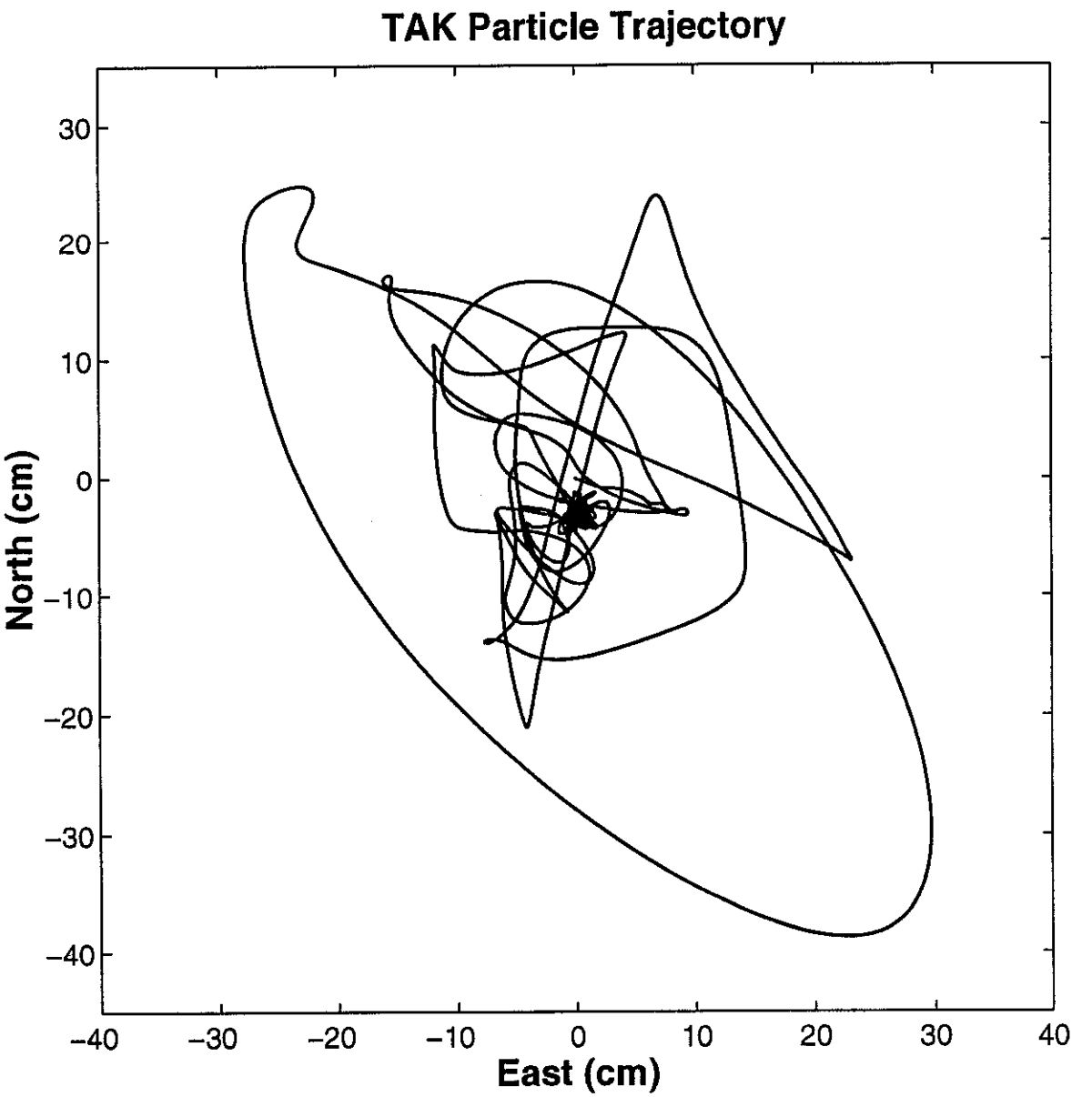

PAR (S17W)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5

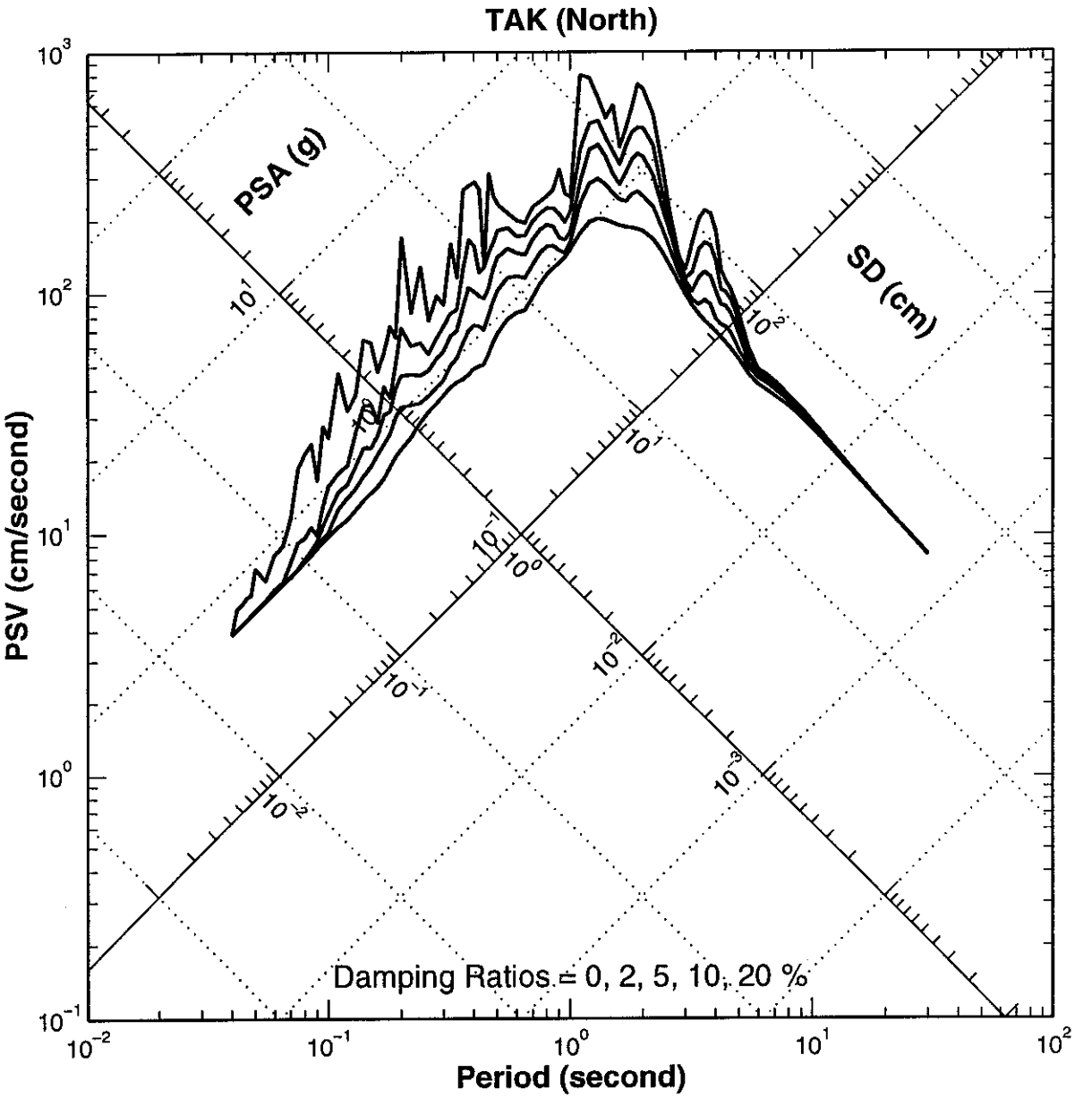
TAKATORI STATION (TAK)

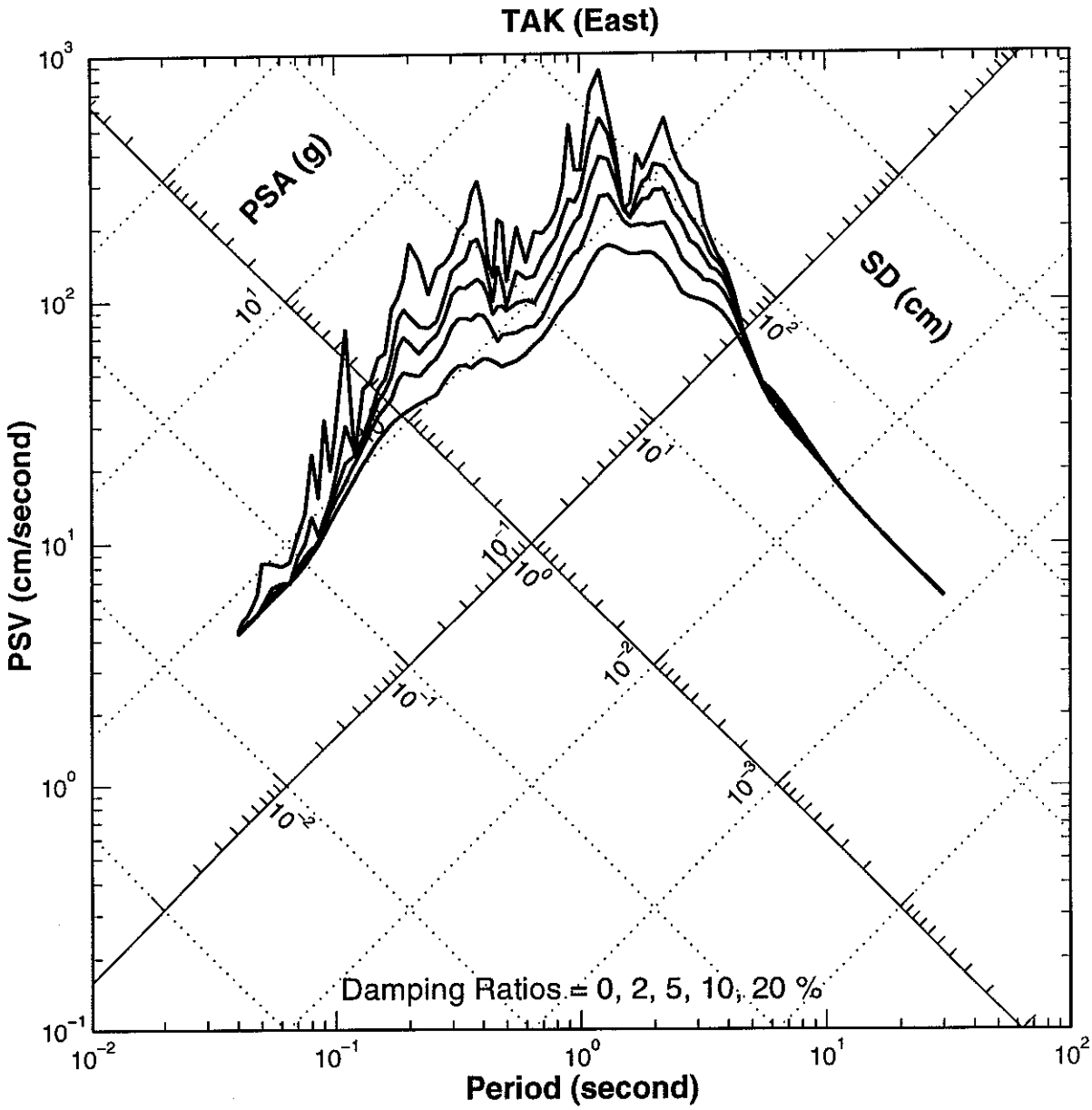

TAK (North)
Max = 600 cm/s/s
Acceleration (cm/s/s)
1000
500
0
−500
−1000
0
5
10
15
20
Max = 121 cm/s
Velocity (cm/s)
200
100
0
−100
−200
Max = −39 cm
Displacemnt (cm)
40
20
0
−20
−40
Time (second)

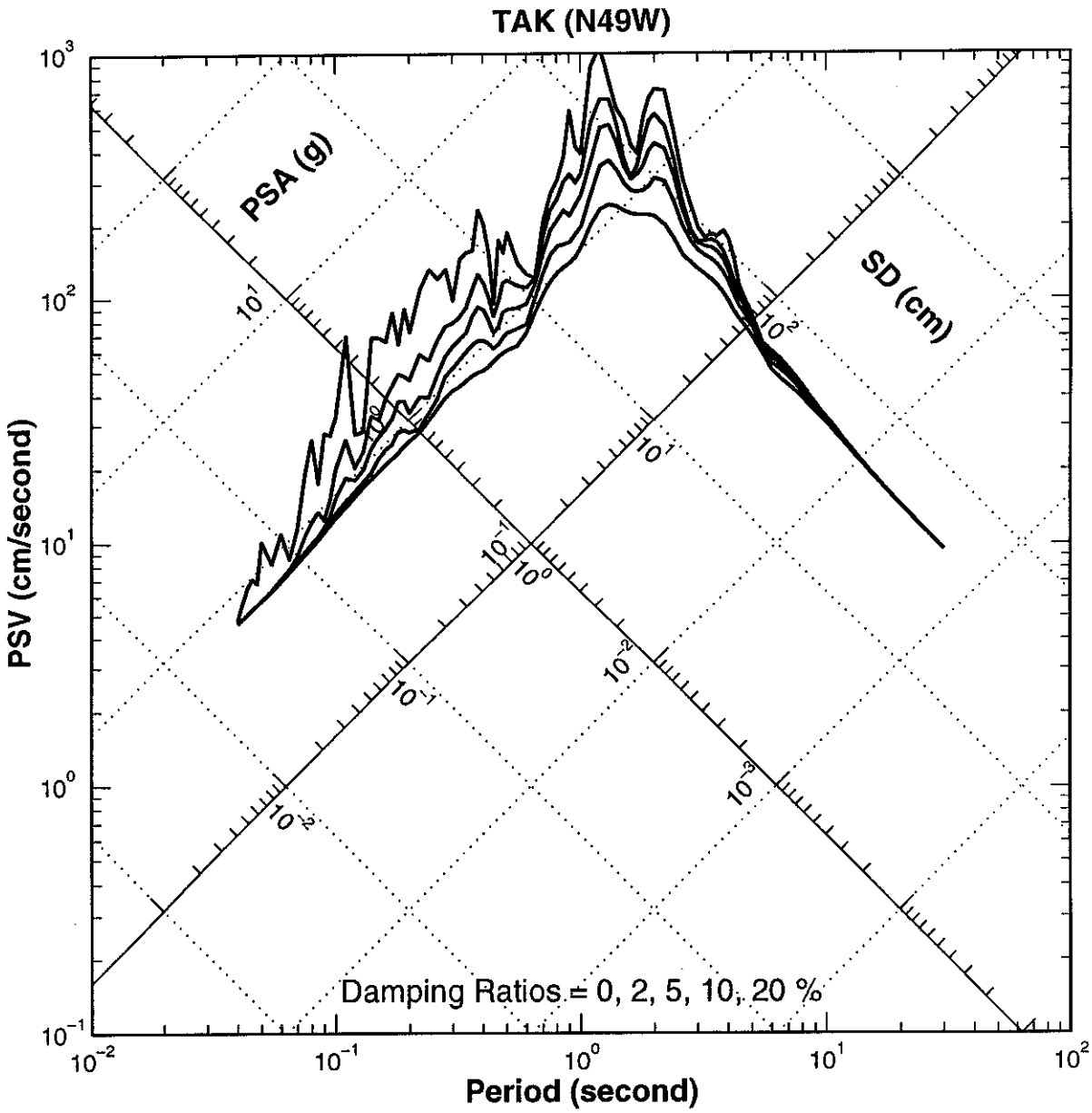

TAK (East)
Max = 637 cm/s/s
Acceleration (cm/s/s)
1000
500
0
−500
−1000
0
5
10
15
20
Max = −124 cm/s
Velocity (cm/s)
100
50
0
−50
−100
−150
Max = 30 cm
Displacemnt (cm)
40
20
0
−20
−40
Time (second)

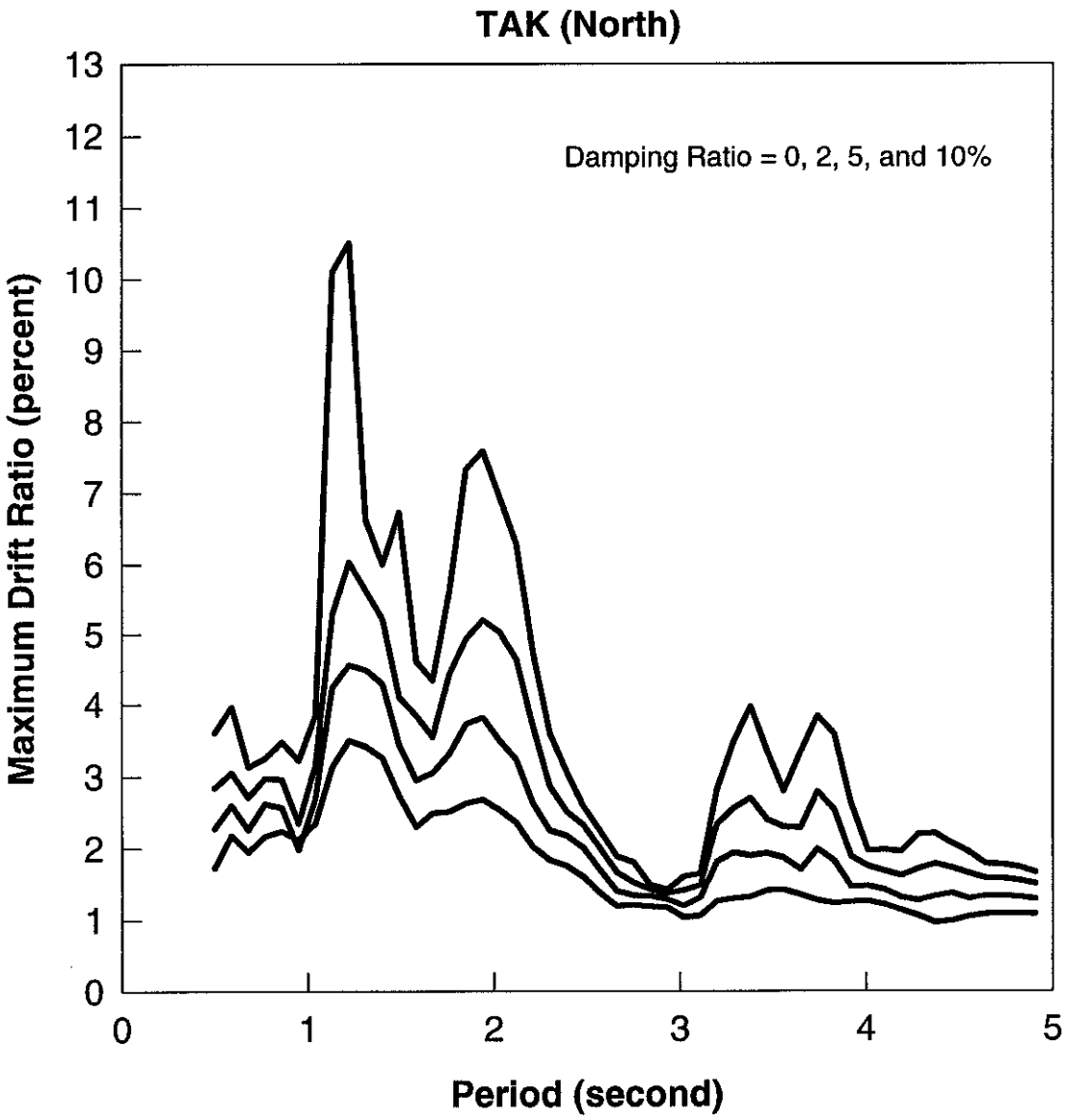

TAK (N49W)
Acceleration (cm/s/s)
Max = 721 cm/s/s
1000
500
0
−500
−1000
0
5
10
15
20
Velocity (cm/s)
Max = 155 cm/s
200
100
0
−100
−200
Displacemnt (cm)
Max = −45 cm
40
20
0
−20
−40
−60
Time (second)

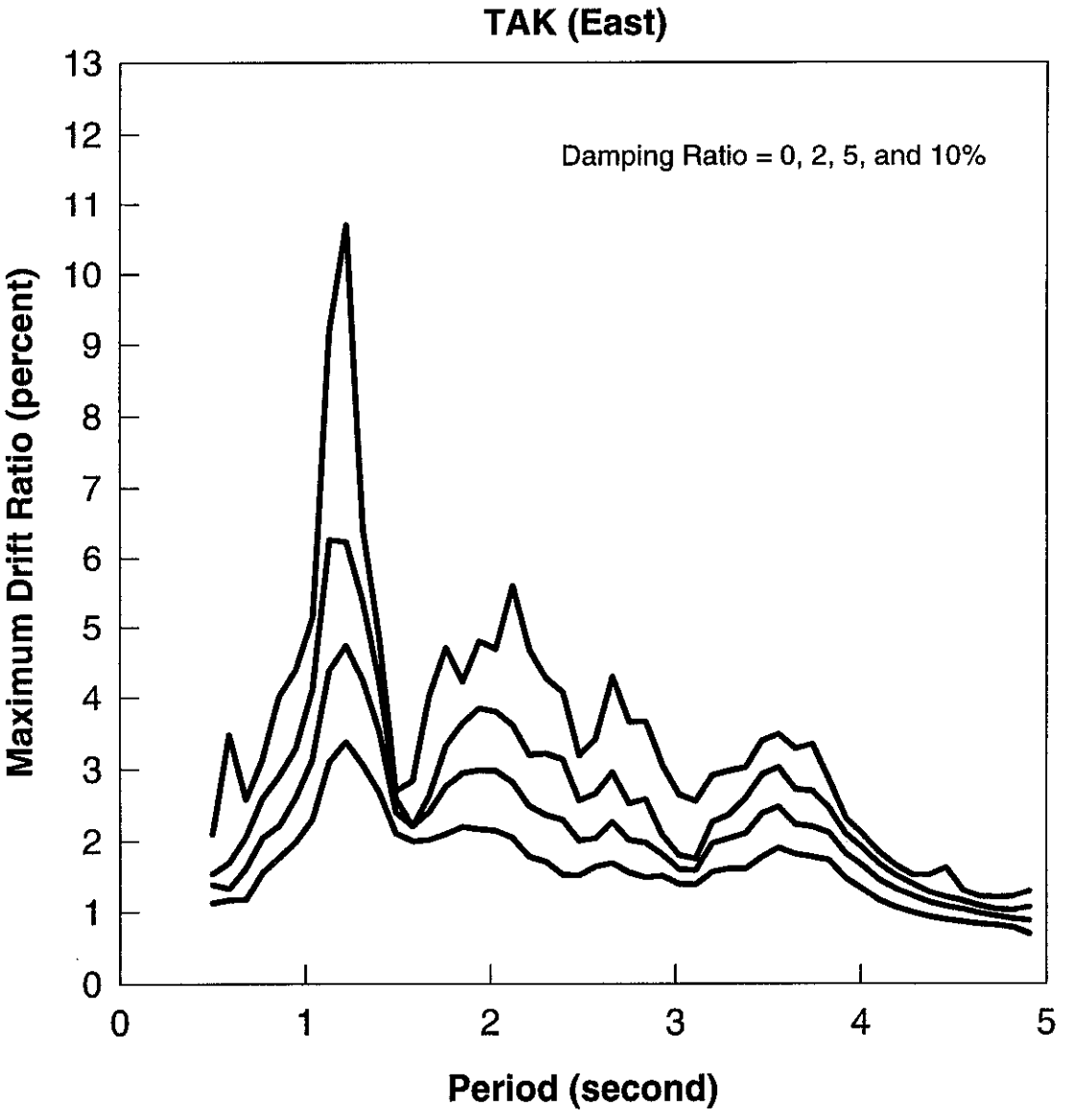

TAK Particle Trajectory
North (cm)
East (cm)
30
20
10
0
−10
−20
−30
−40
−40
−30
−20
−10
0
10
20
30
40

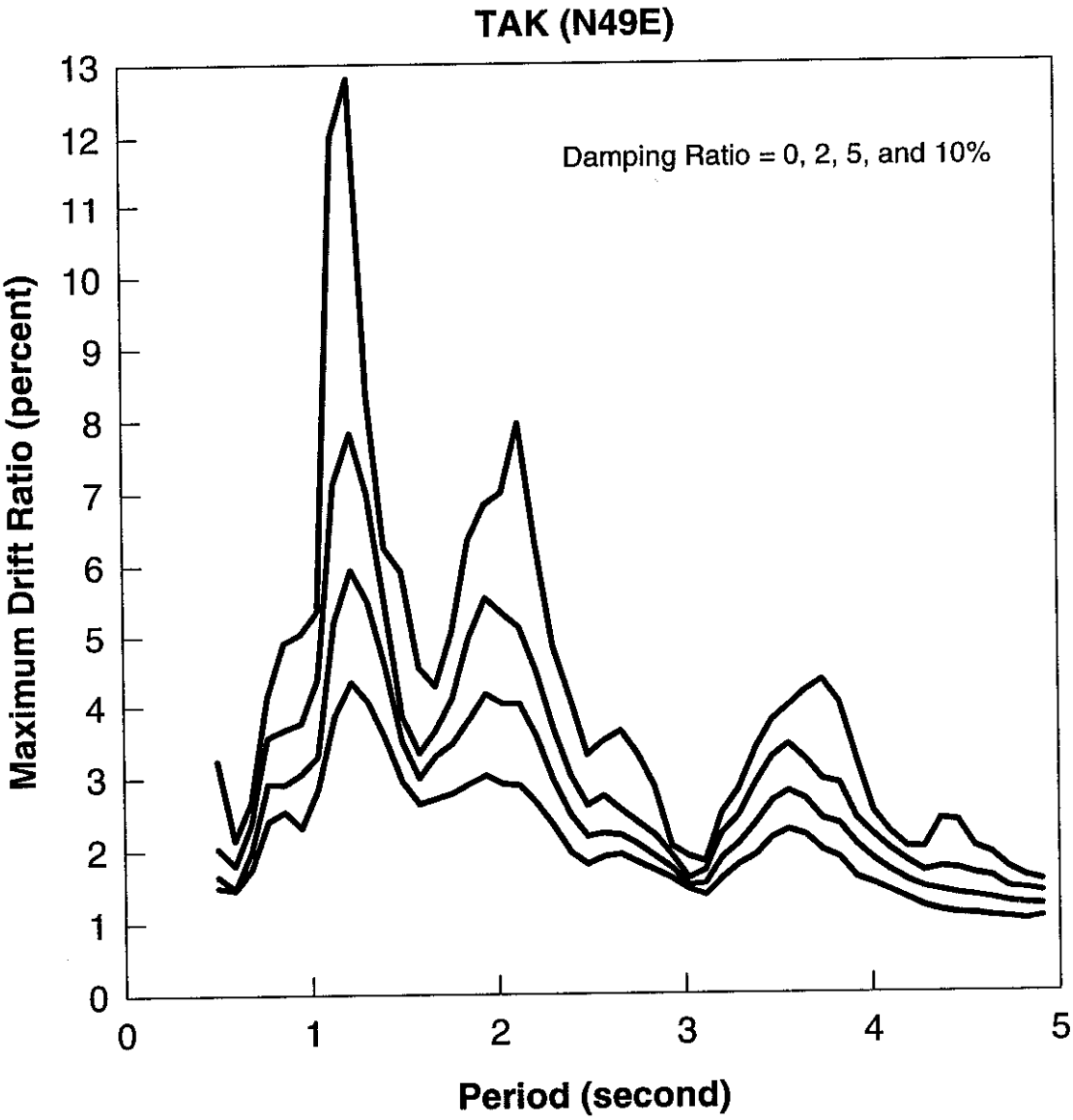

TAK (North)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %


TAK (East)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %

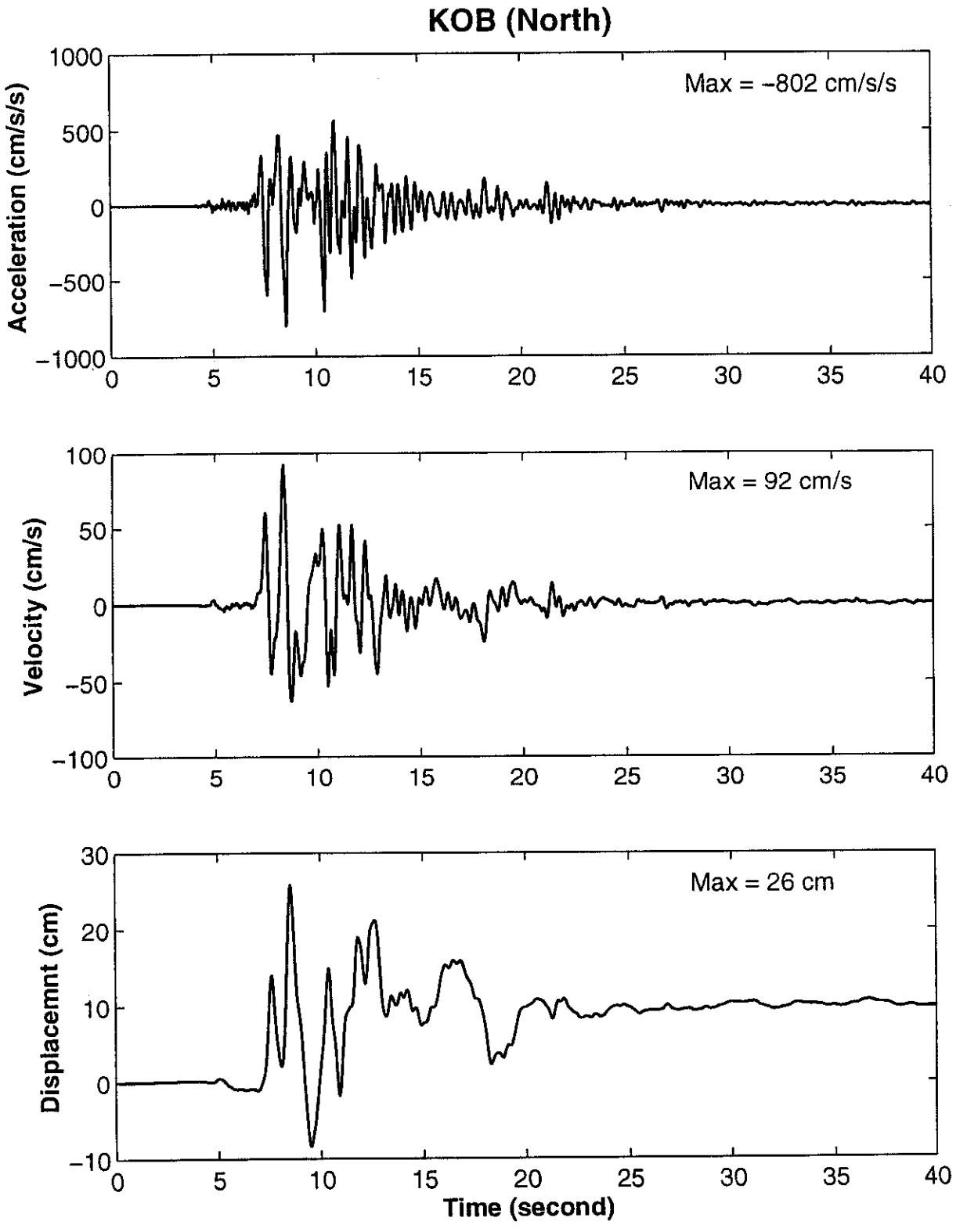

TAK (N49W)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %

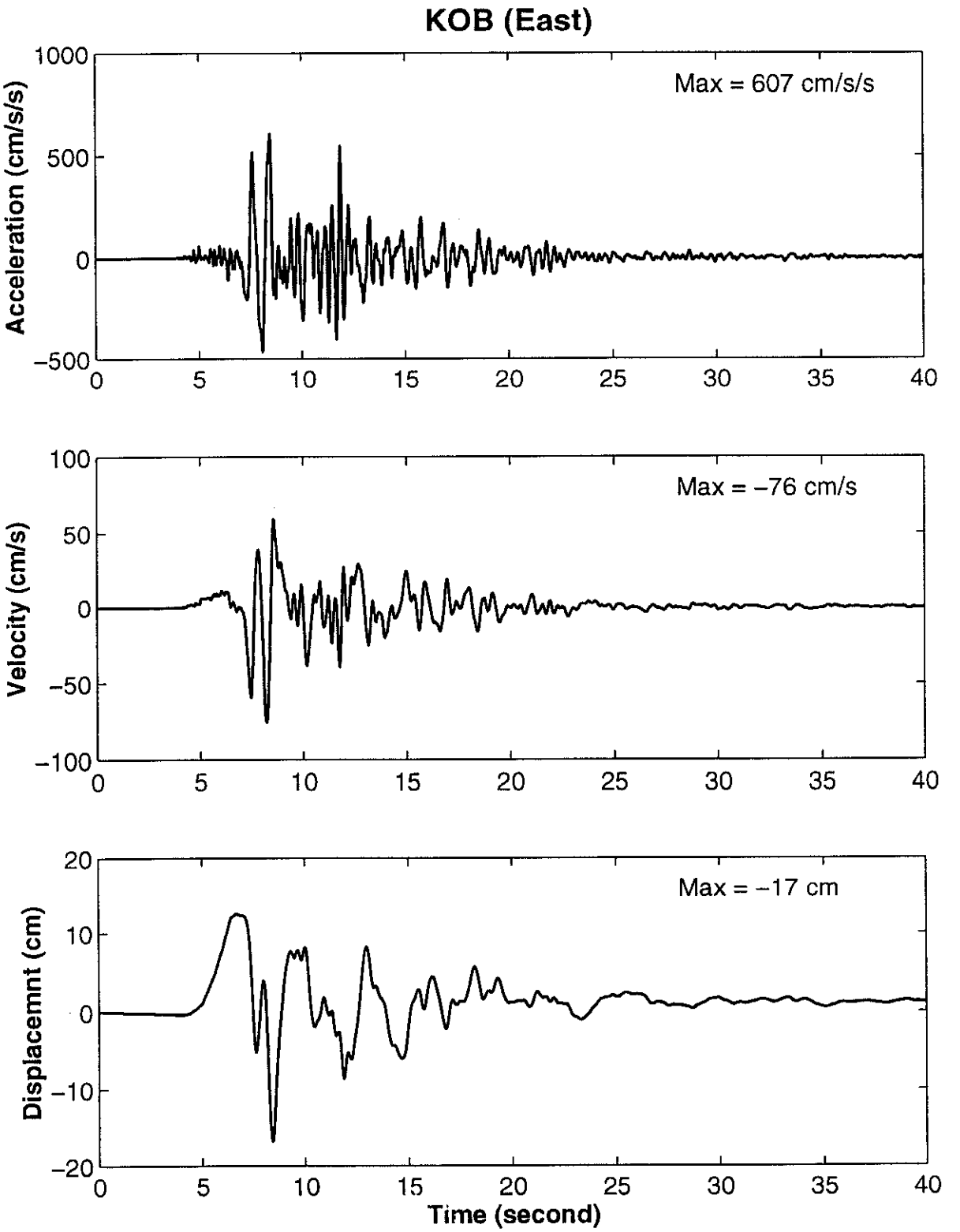

TAK (North)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
9
10
11
12
13

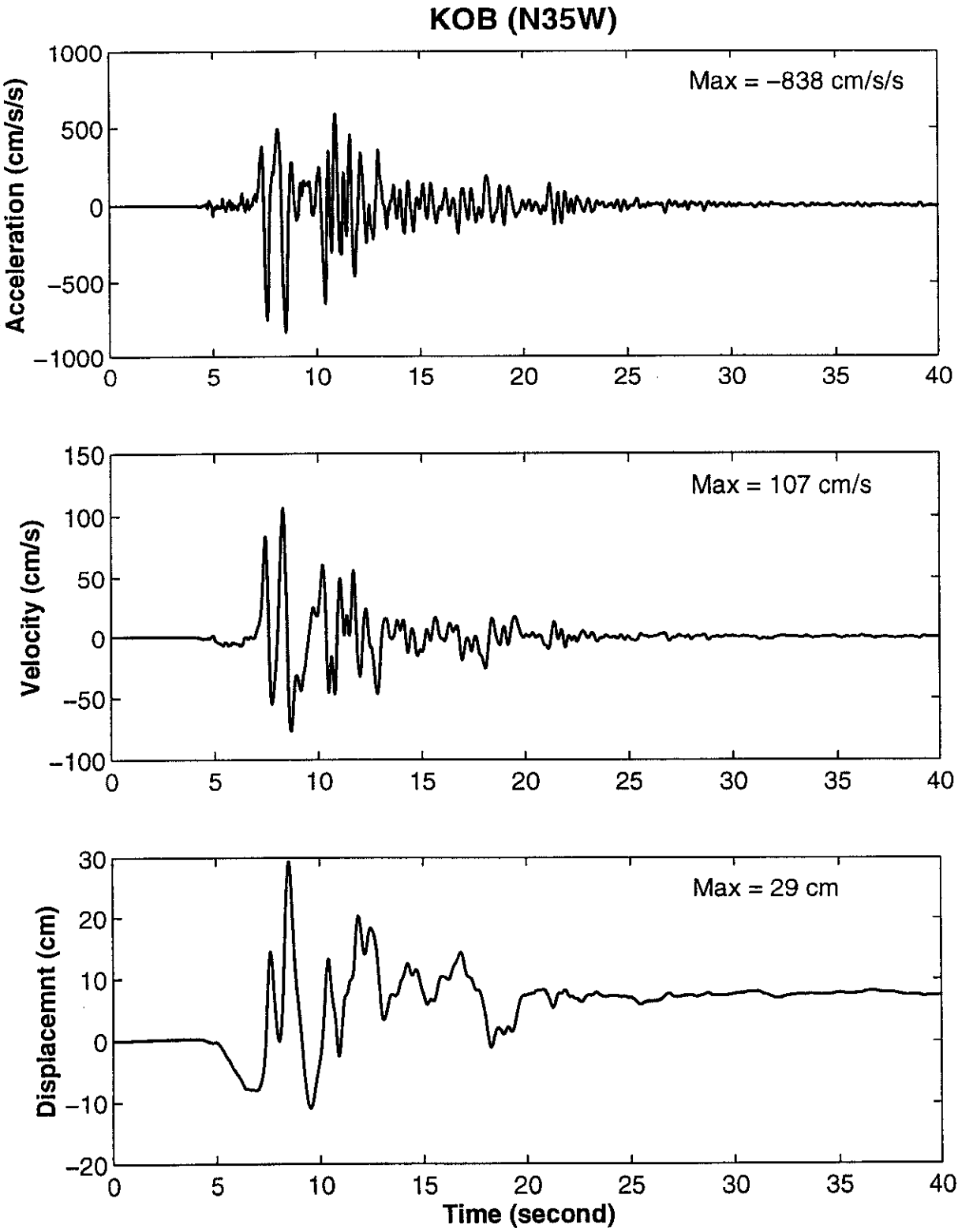

TAK (East)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
9
10
11
12
13

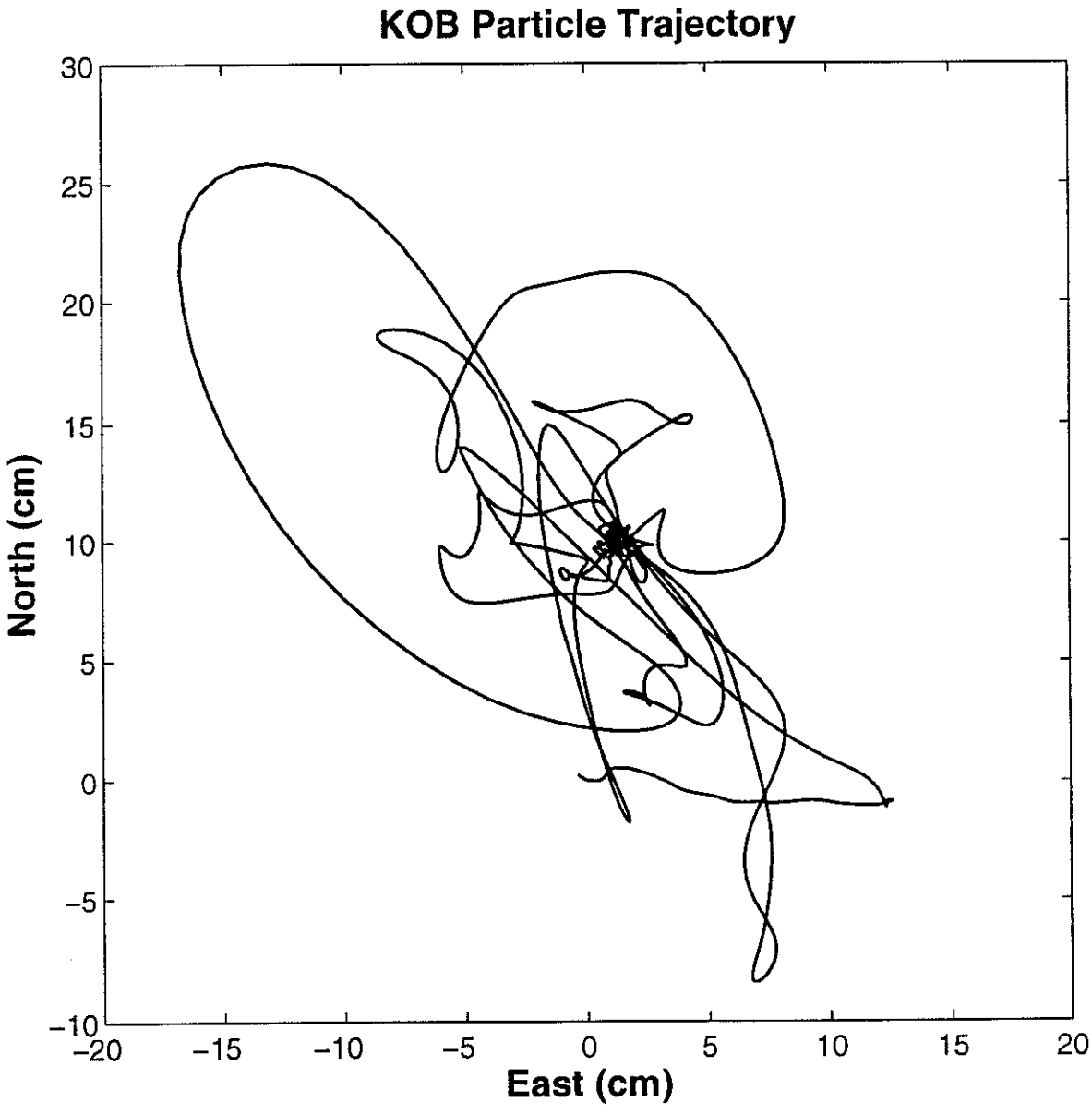

TAK (N49E)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
9
10
11
12
13

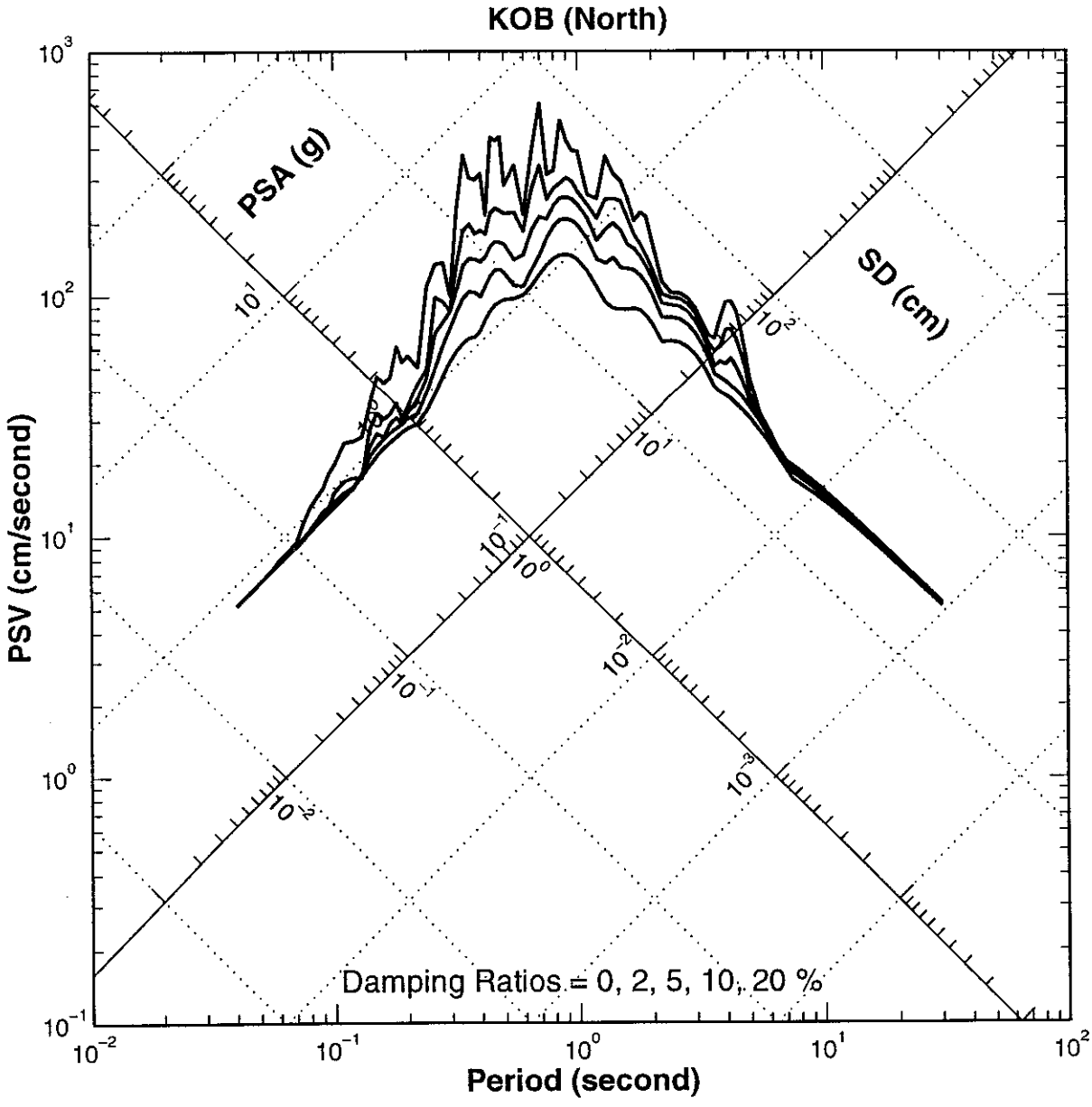
KOBE STATION (KOB)

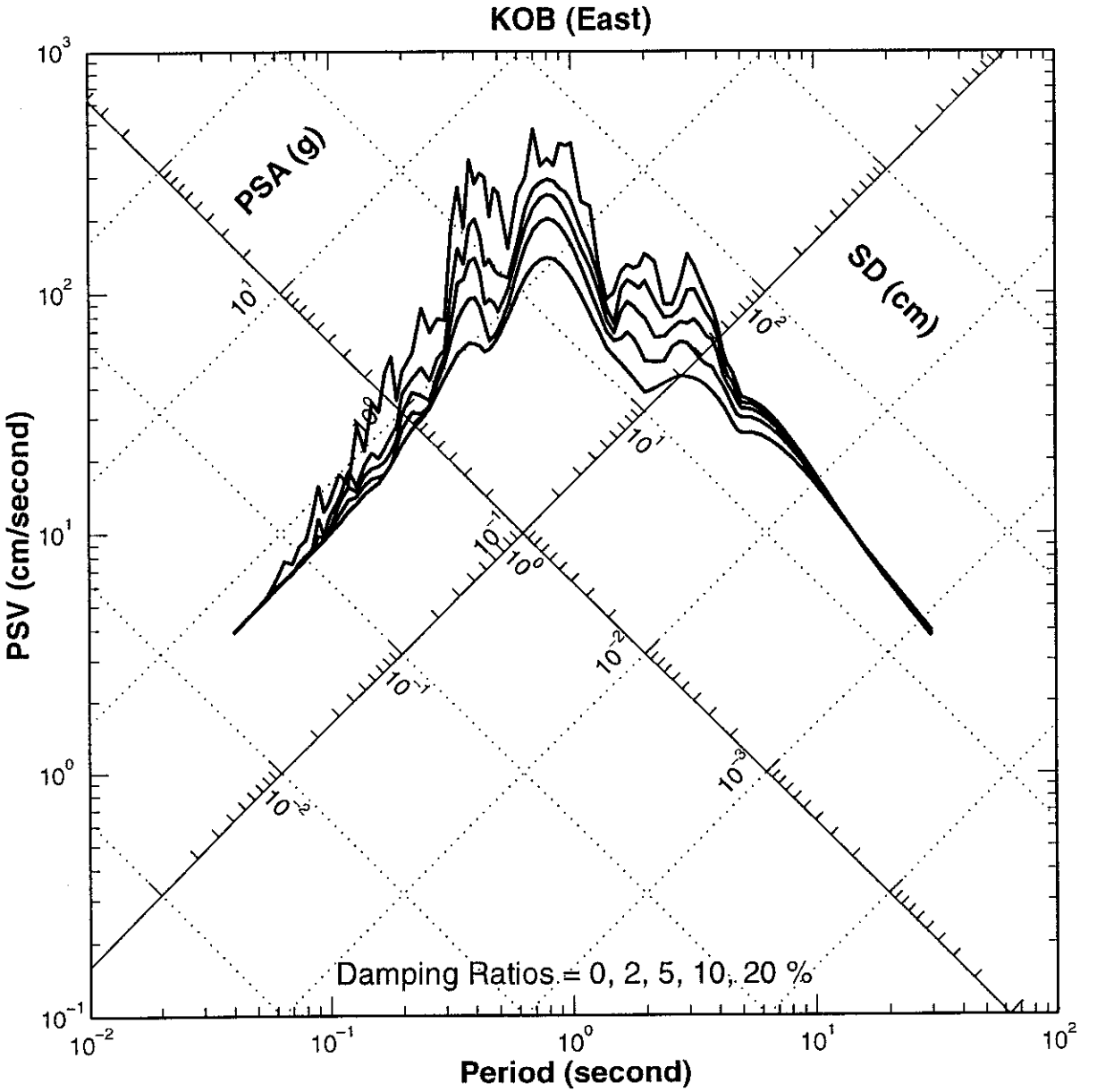

KOB (North)
Max = −802 cm/s/s
Acceleration (cm/s/s)
1000
500
0
−500
−1000
Max = 92 cm/s
Velocity (cm/s)
100
50
0
−50
−100
Max = 26 cm
Displacemnt (cm)
30
20
10
0
−10
0
5
10
15
20
25
30
35
40
Time (second)

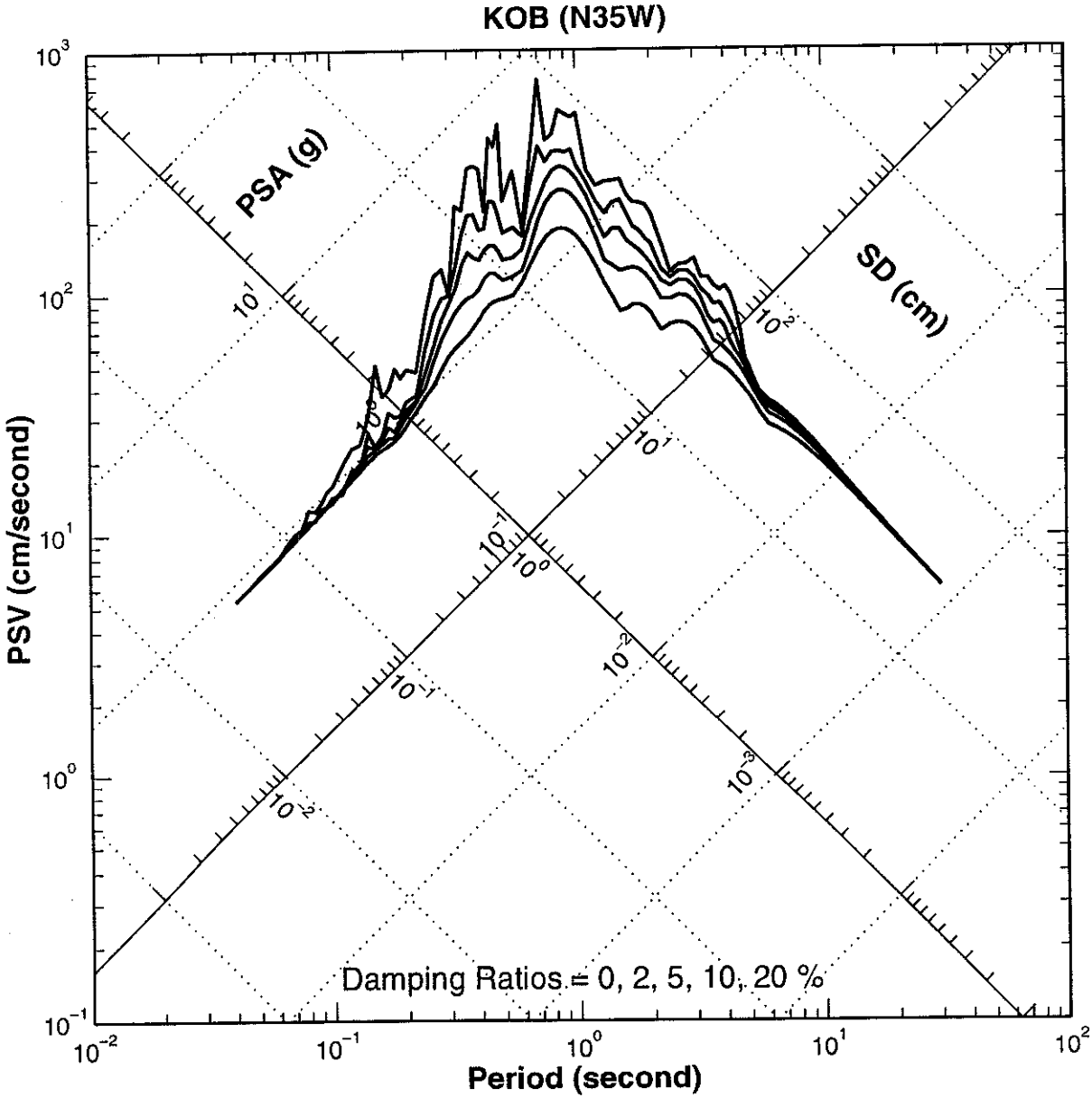

KOB (East)
Max = 607 cm/s/s
Acceleration (cm/s/s)
1000
500
0
−500
Max = −76 cm/s
Velocity (cm/s)
100
50
0
−50
−100
Max = −17 cm
Displacemnt (cm)
20
10
0
−10
−20
0
5
10
15
20
25
30
35
40
Time (second)

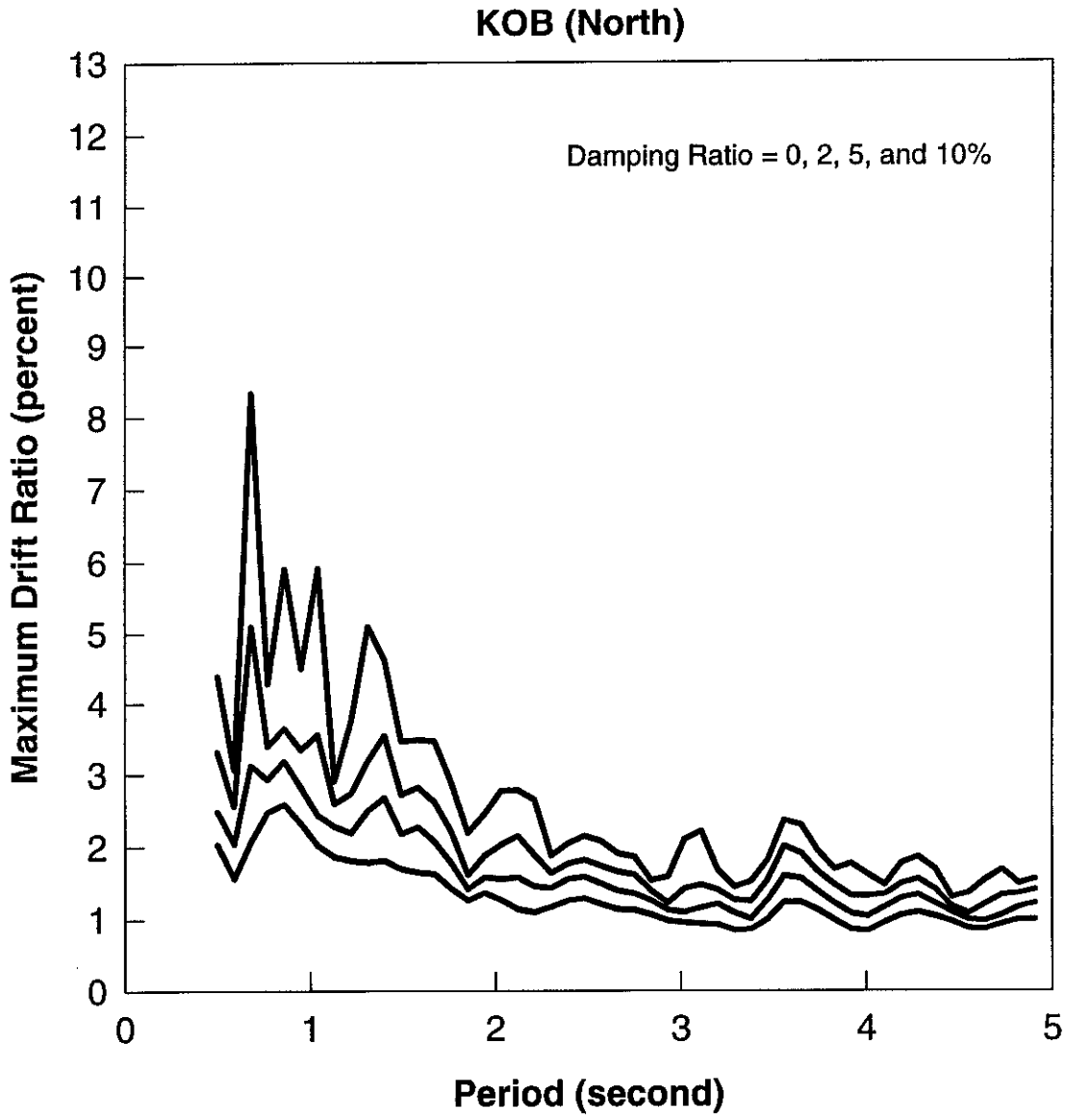

KOB (N35W)
Max = −838 cm/s/s
Acceleration (cm/s/s)
1000
500
0
−500
−1000
Max = 107 cm/s
Velocity (cm/s)
150
100
50
0
−50
−100
Max = 29 cm
Displacemnt (cm)
30
20
10
0
−10
−20
0
5
10
15
20
25
30
35
40
Time (second)

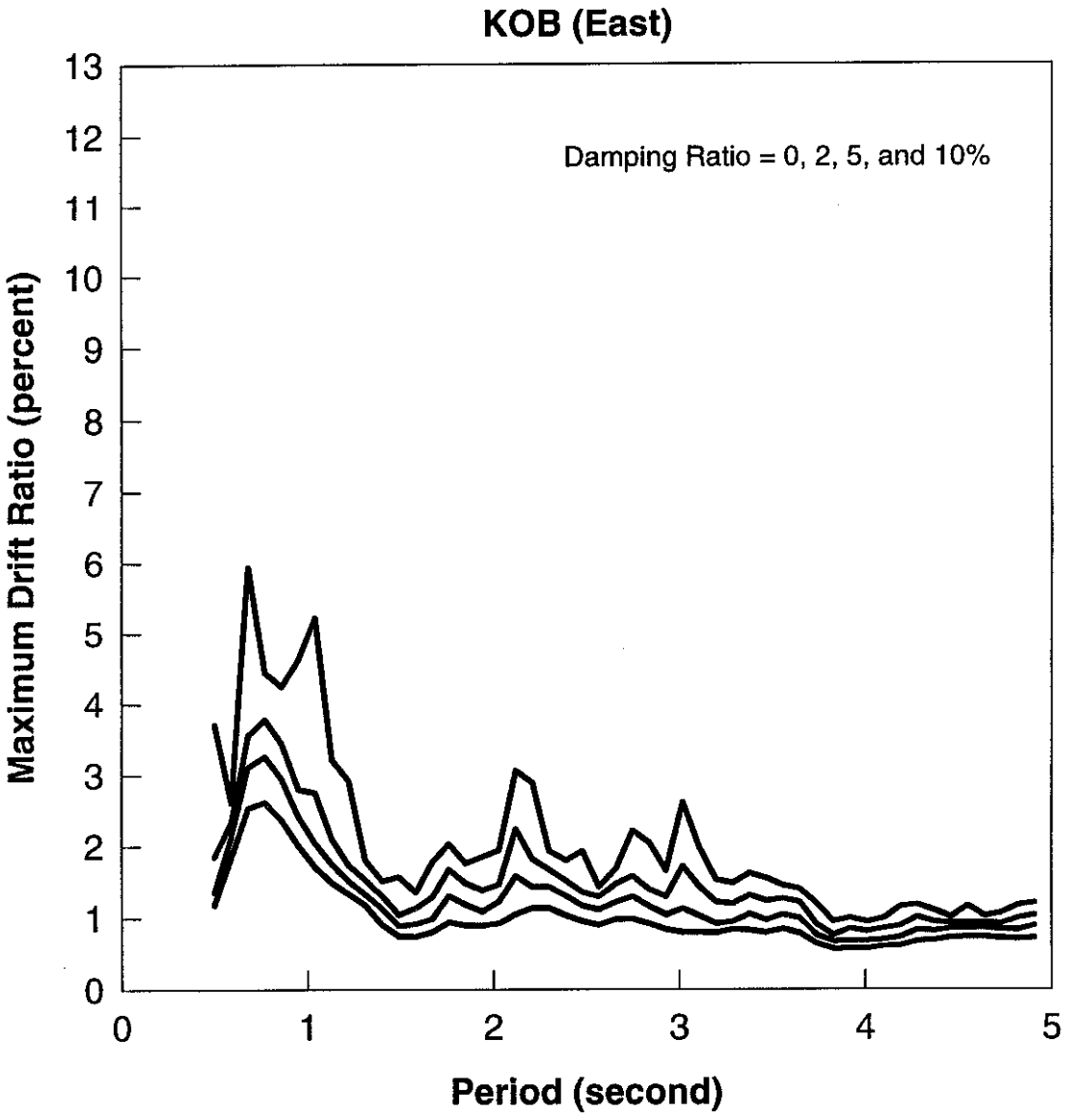

KOB Particle Trajectory
North (cm)
East (cm)
30
25
20
15
10
5
0
−5
−10
−20
−15
−10
−5
0
5
10
15
20

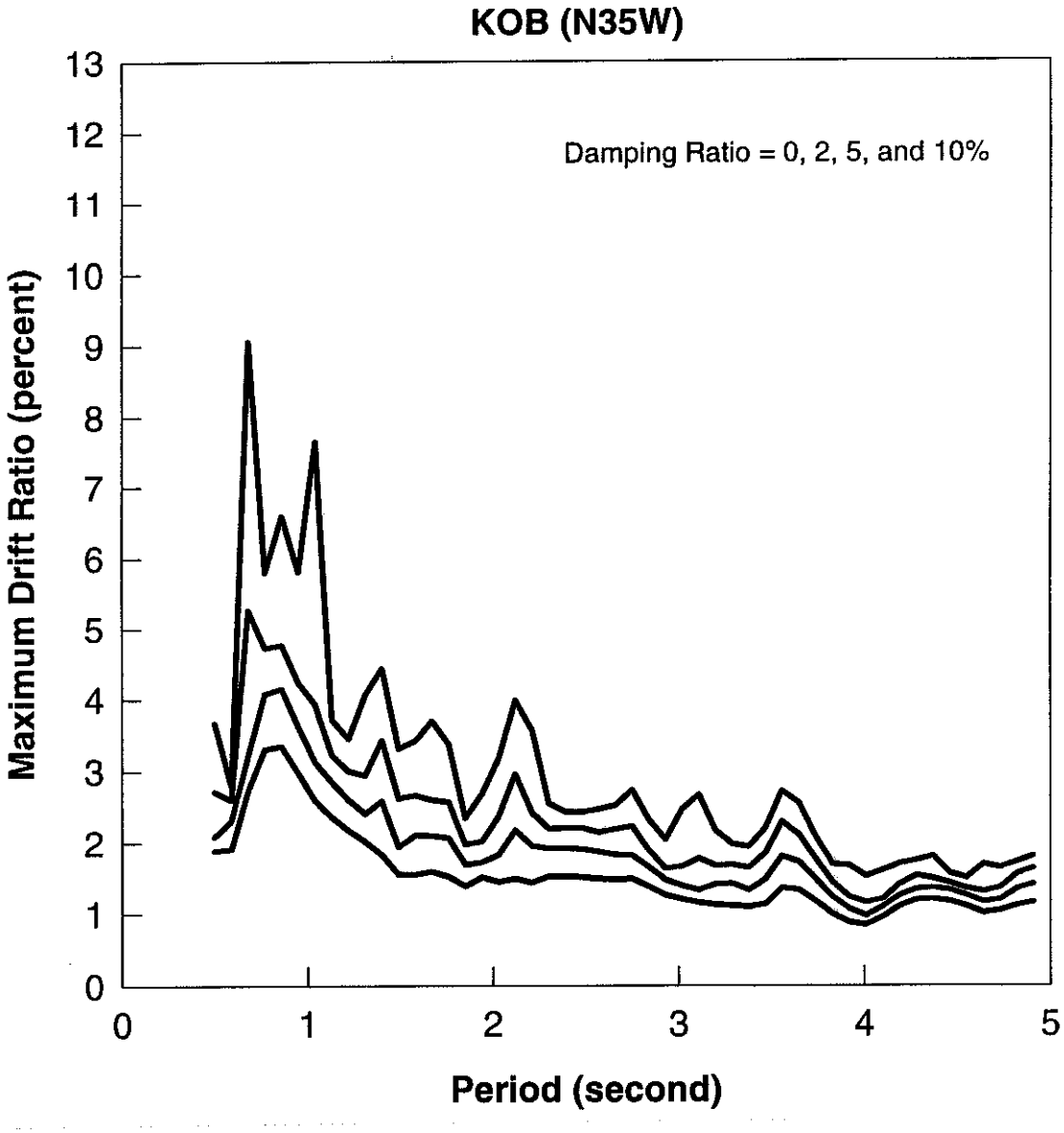

KOB (North)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %


KOB (East)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %

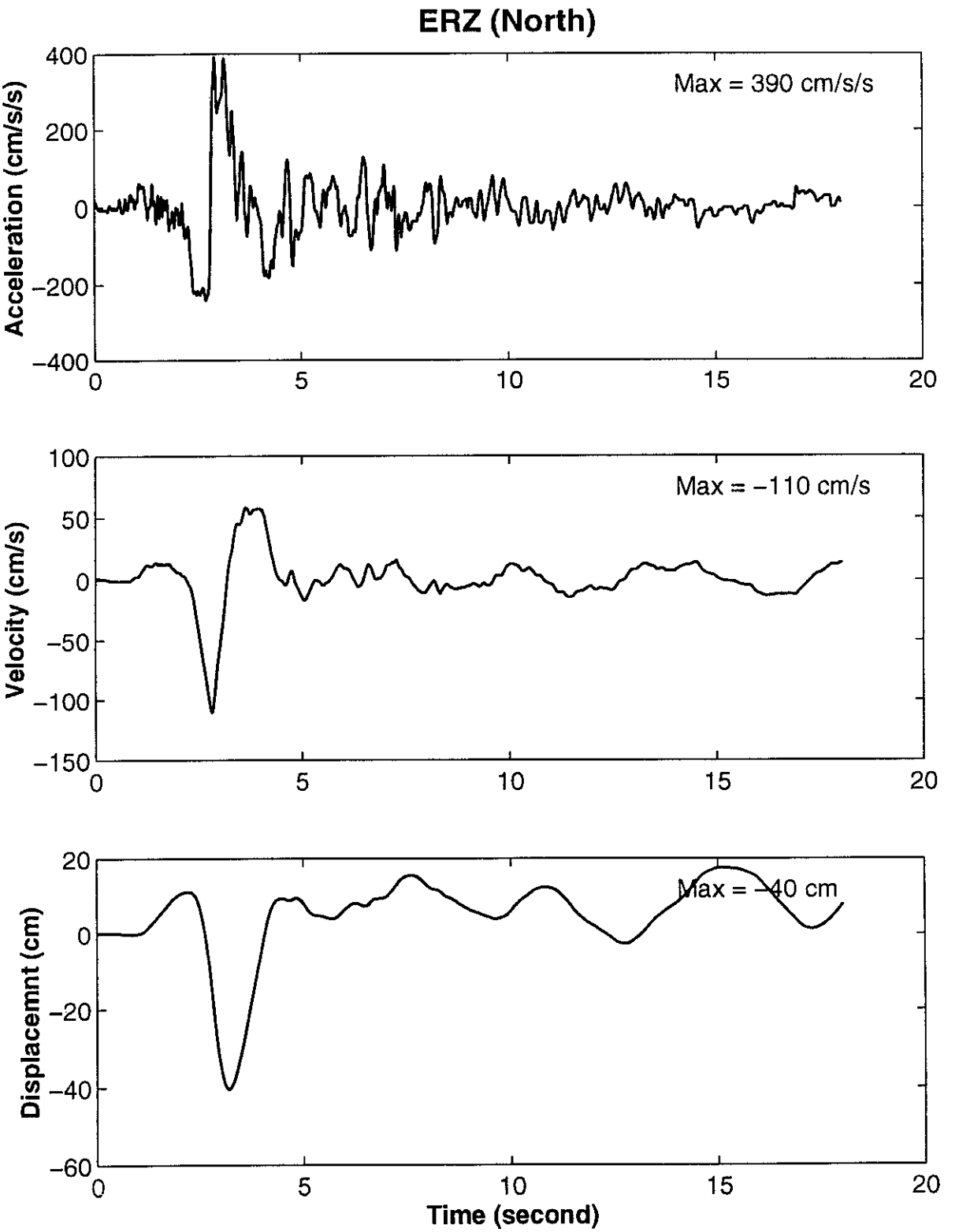

KOB (N35W)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %

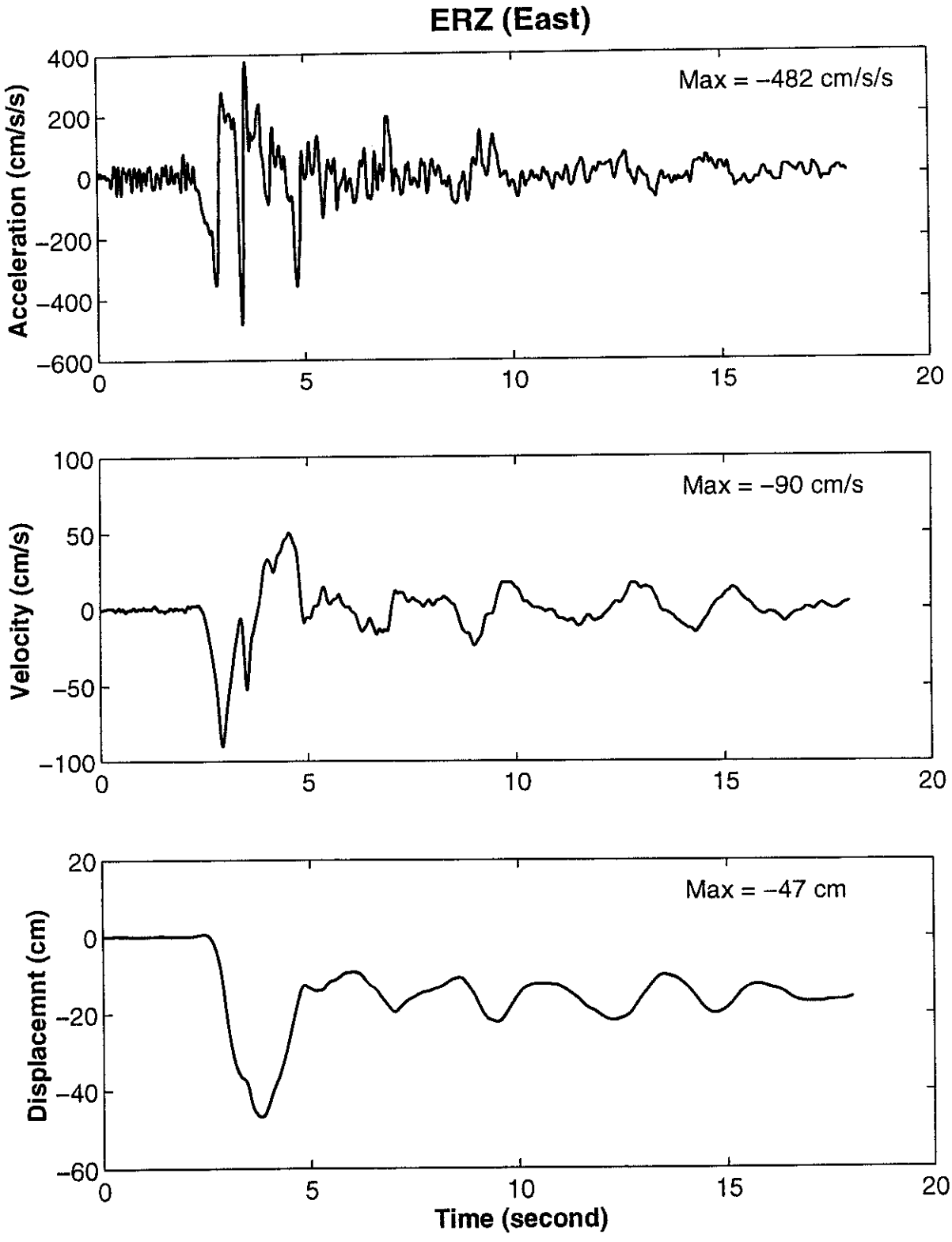

KOB (North)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
9
10
11
12
13

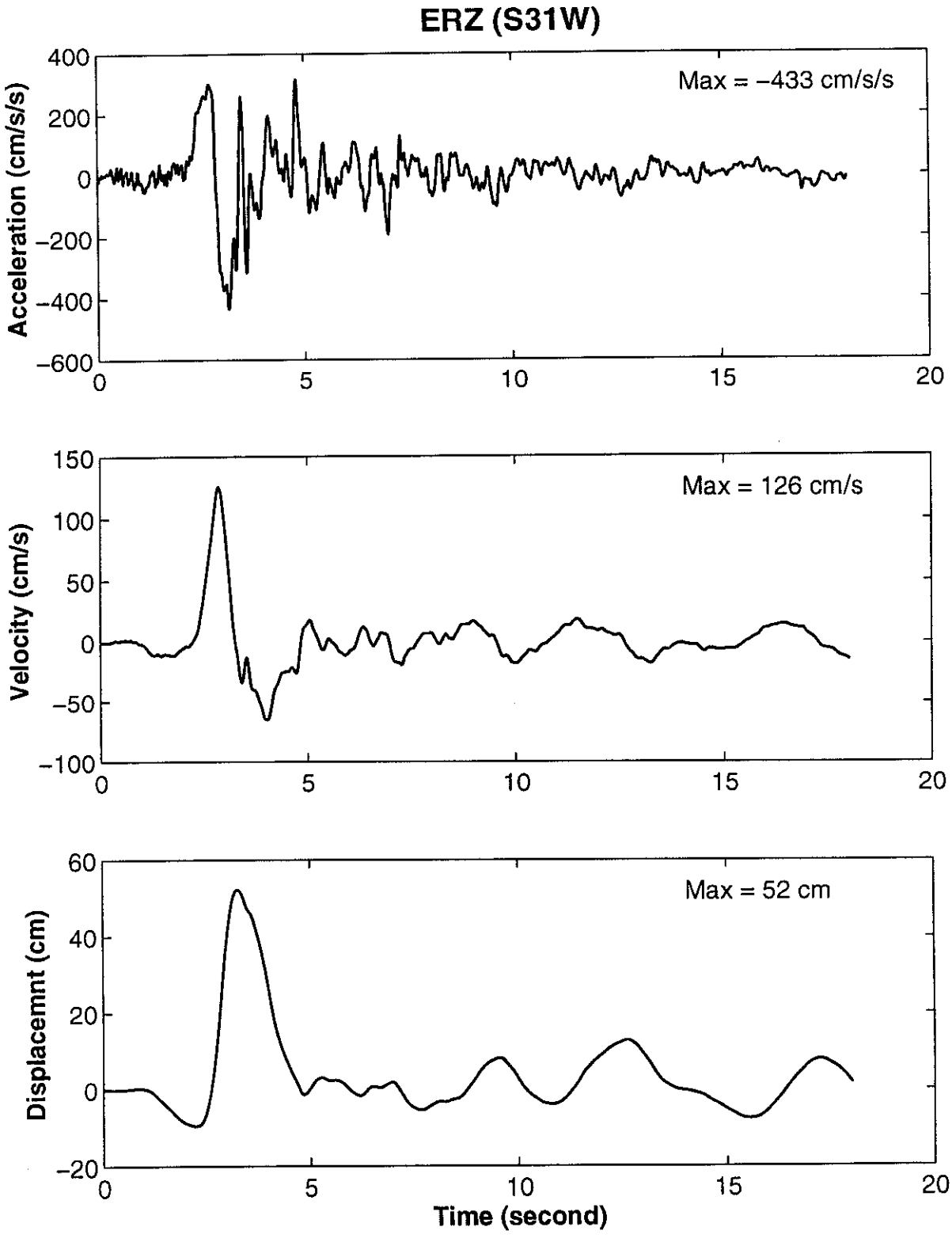

KOB (East)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
9
10
11
12
13

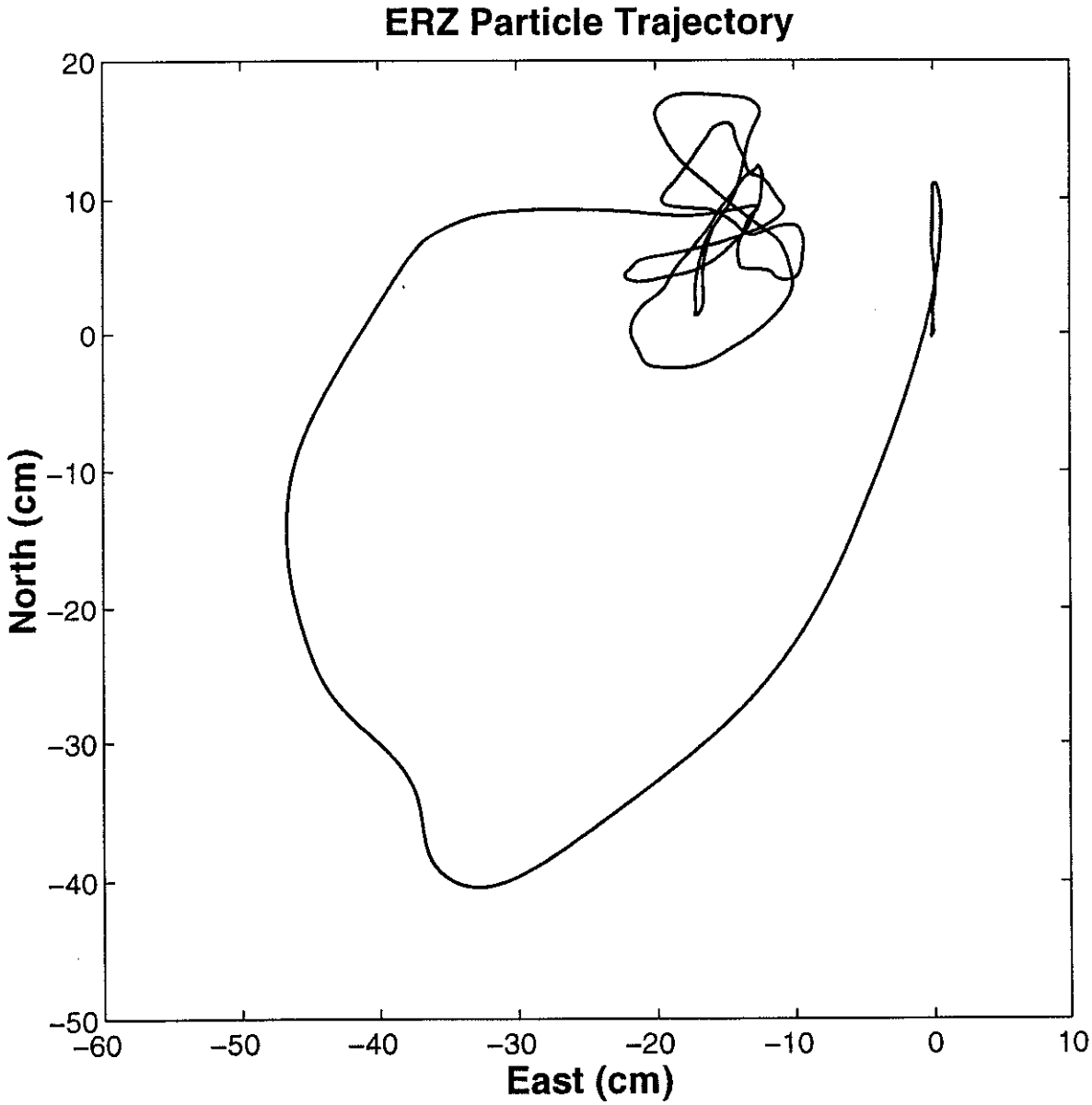

KOB (N35W)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
9
10
11
12
13

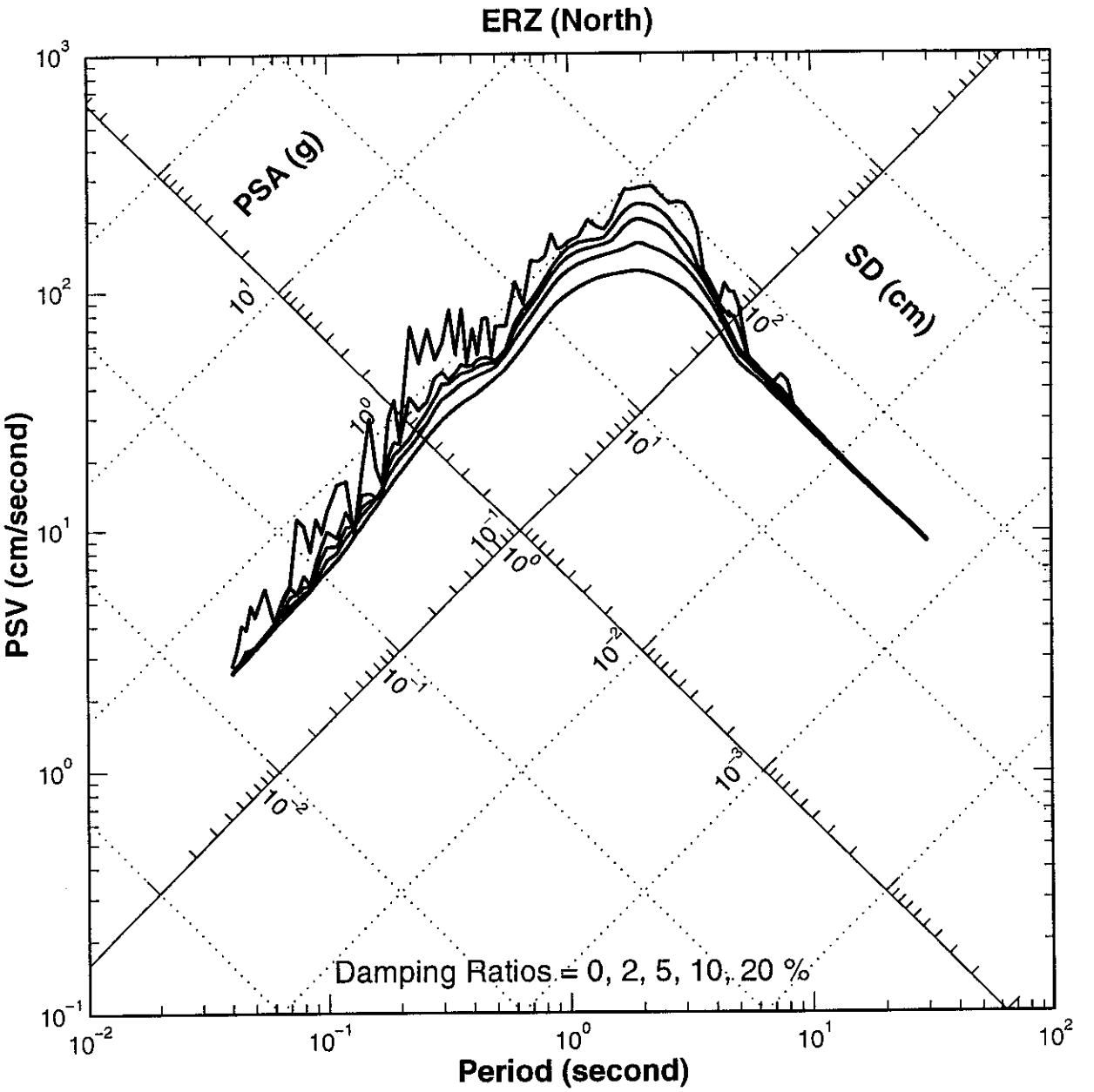
ERZINCAN STATION (ERZ)

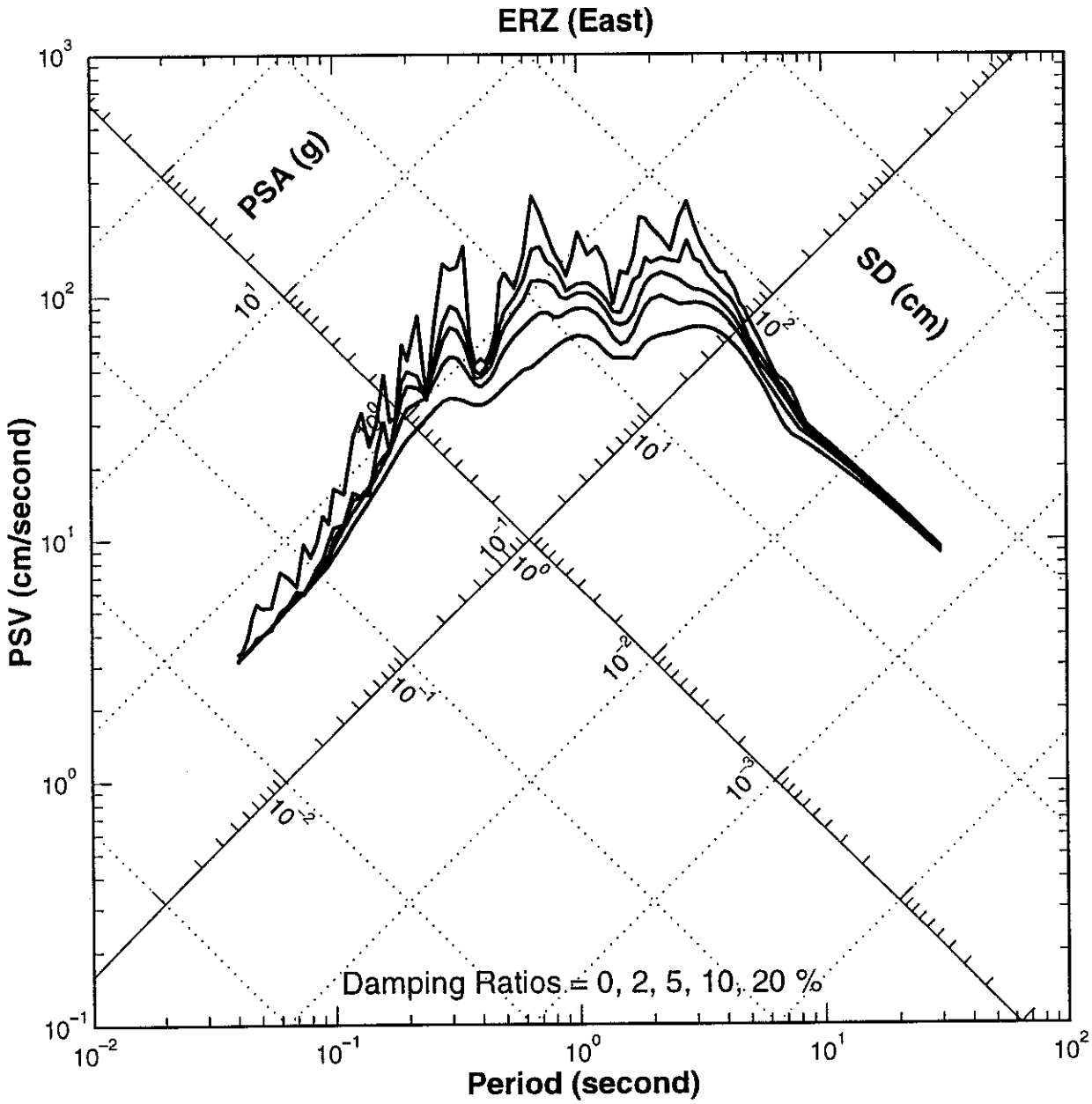

ERZ (North)
Acceleration (cm/s/s)
Max = 390 cm/s/s
400
200
0
−200
−400
0
5
10
15
20
Velocity (cm/s)
Max = −110 cm/s
100
50
0
−50
−100
−150
Displacemnt (cm)
Max = −40 cm
20
0
−20
−40
−60
Time (second)

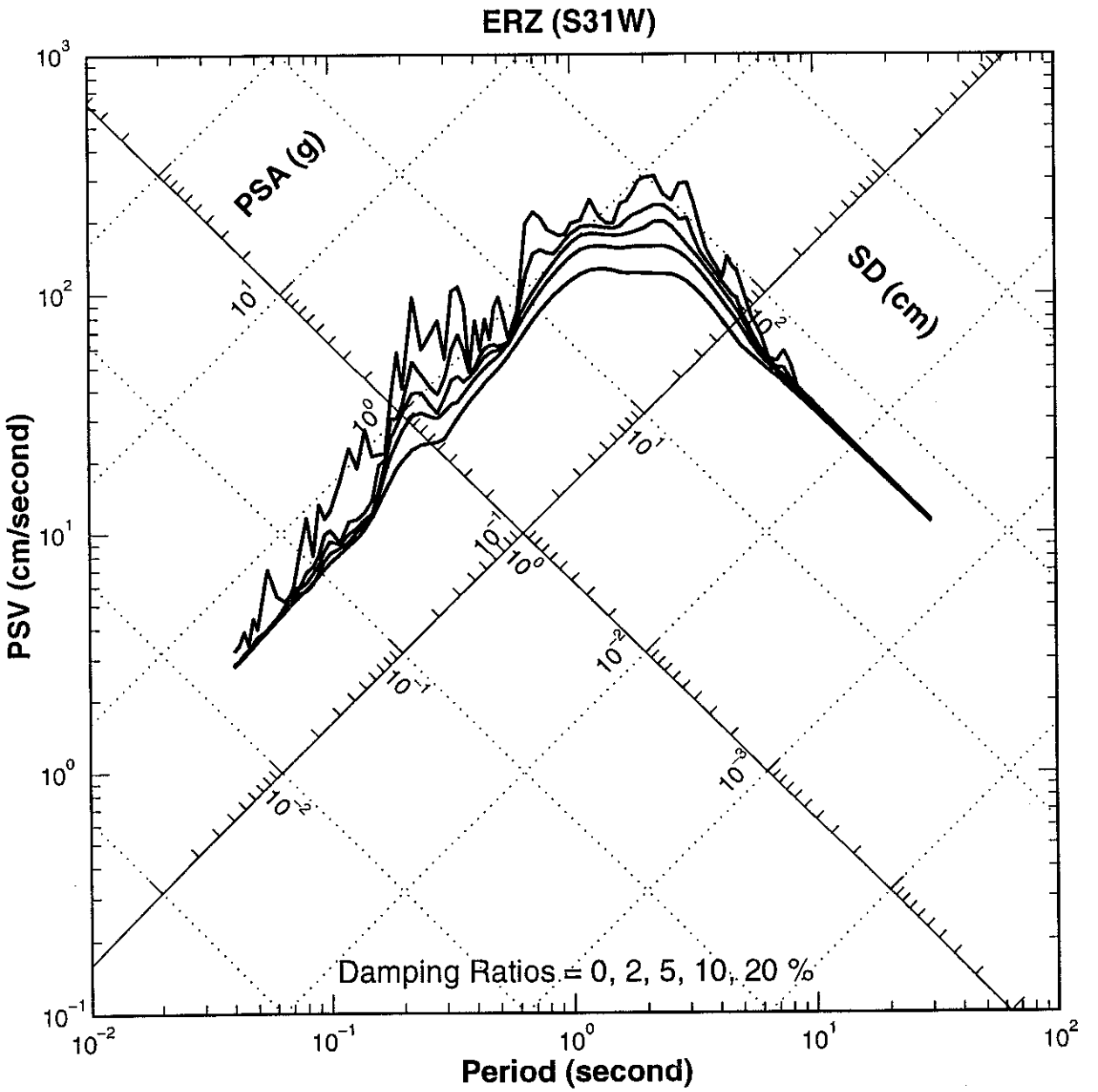

ERZ (East)
Max = −482 cm/s/s
Acceleration (cm/s/s)
400
200
0
−200
−400
−600
0
5
10
15
20
Max = −90 cm/s
Velocity (cm/s)
100
50
0
−50
−100
Max = −47 cm
Displacemnt (cm)
20
0
−20
−40
−60
Time (second)

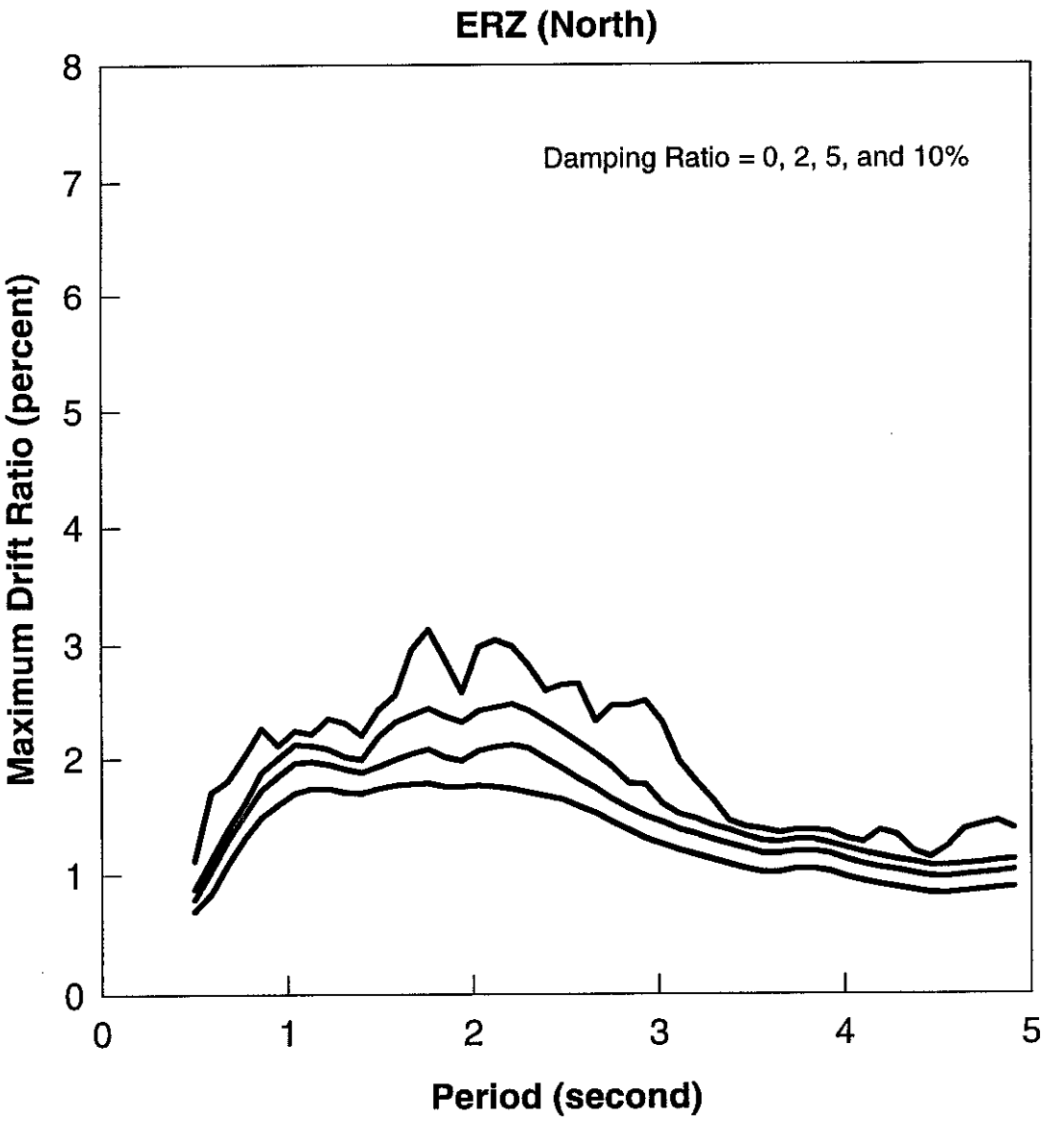

ERZ (S31W)
Max = −433 cm/s/s
Acceleration (cm/s/s)
400
200
0
−200
−400
−600
0
5
10
15
20
Max = 126 cm/s
Velocity (cm/s)
150
100
50
0
−50
−100
Max = 52 cm
Displacemnt (cm)
60
40
20
0
−20
Time (second)

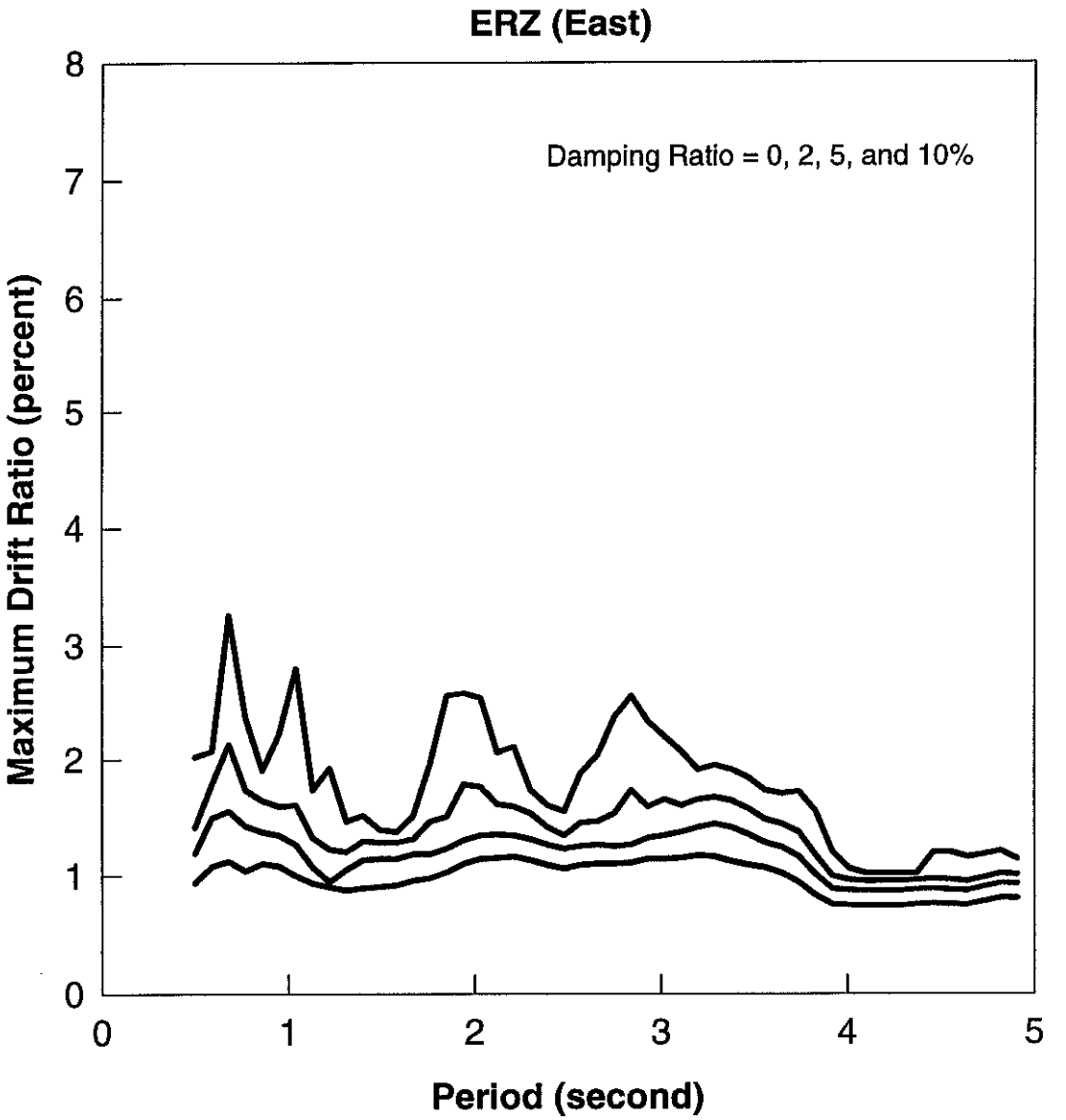

ERZ Particle Trajectory
North (cm)
East (cm)
20
10
0
−10
−20
−30
−40
−50
−60
−50
−40
−30
−20
−10
0
10

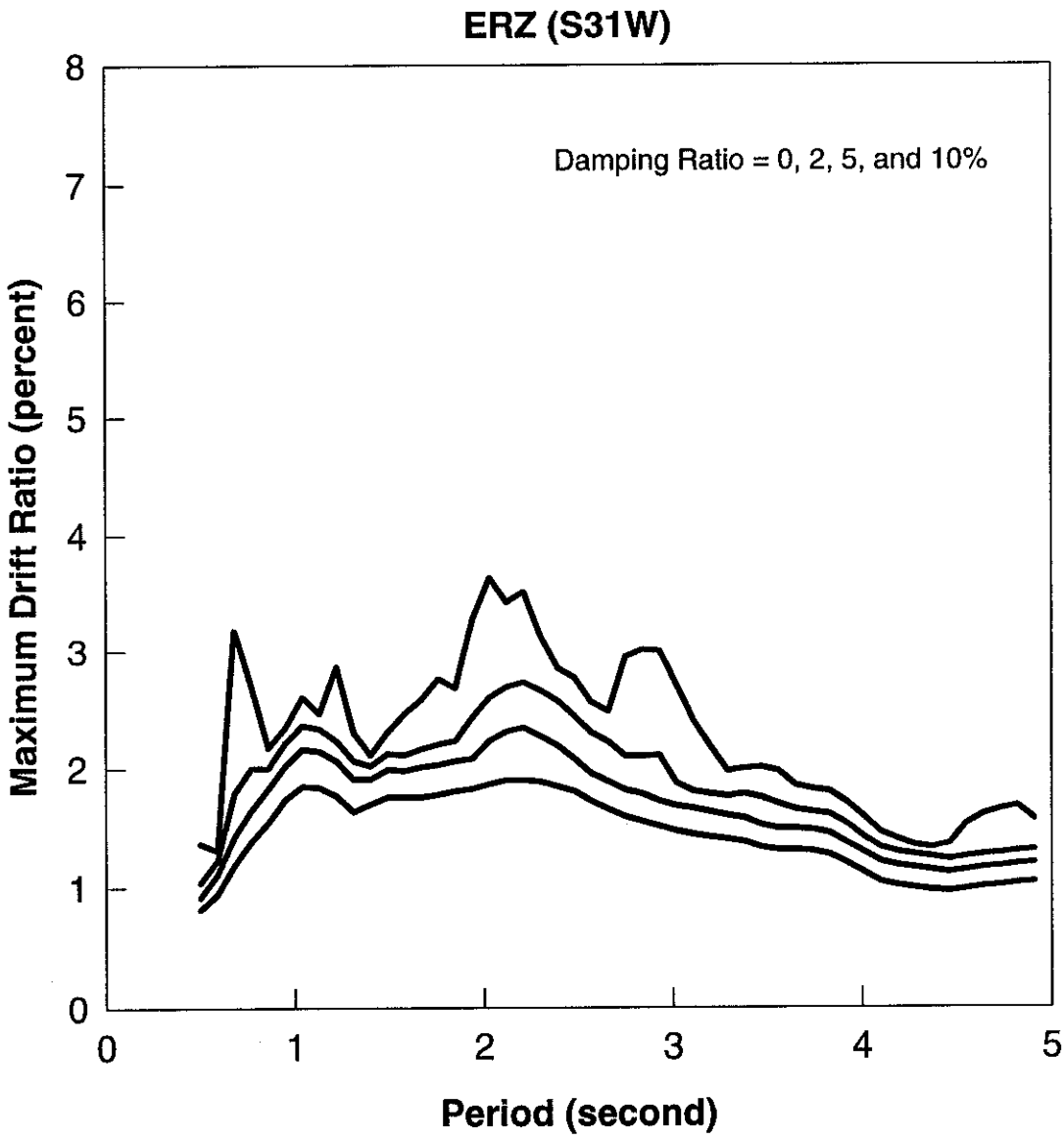

ERZ (North)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %


ERZ (East)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %


ERZ (S31W)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %

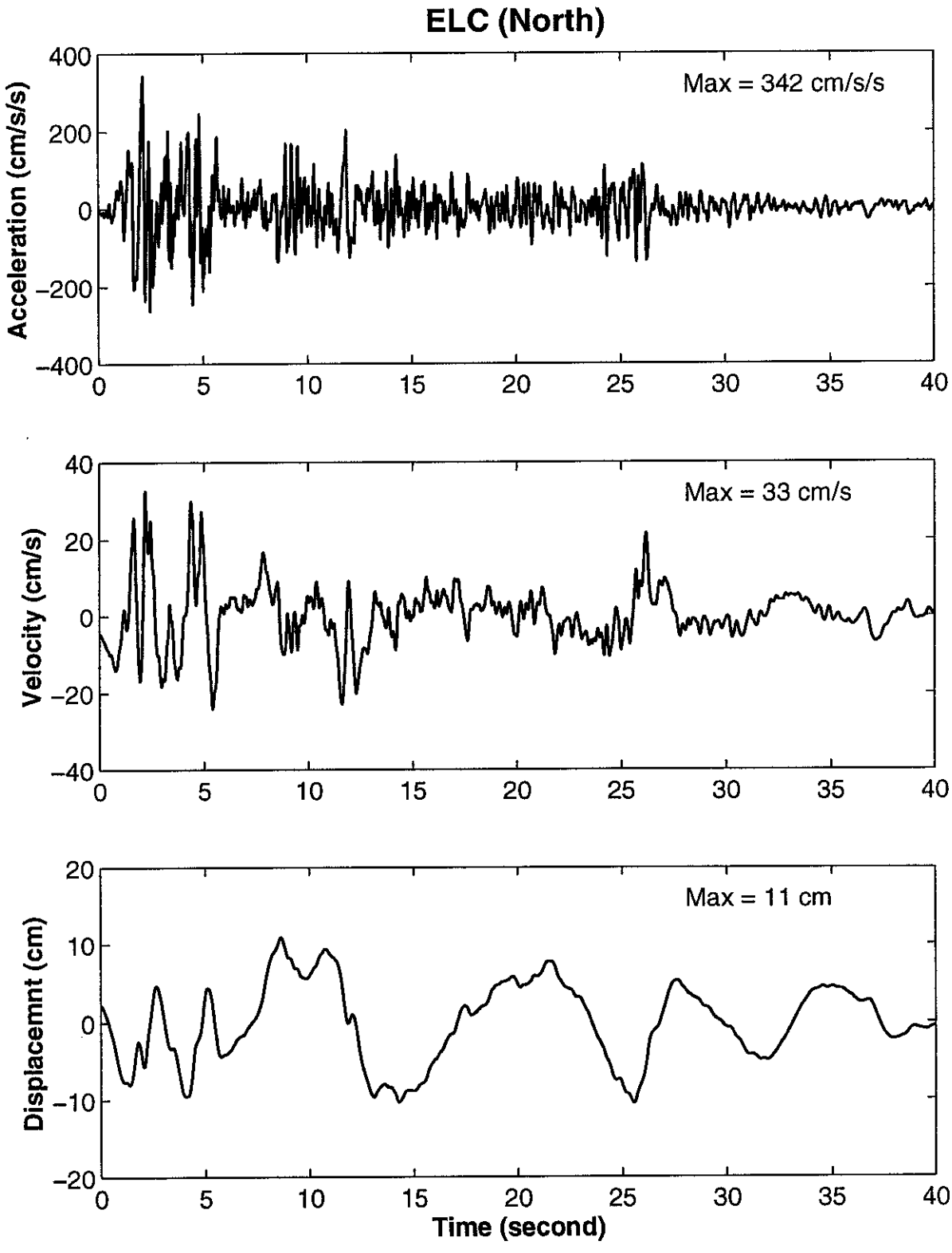

ERZ (North)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5

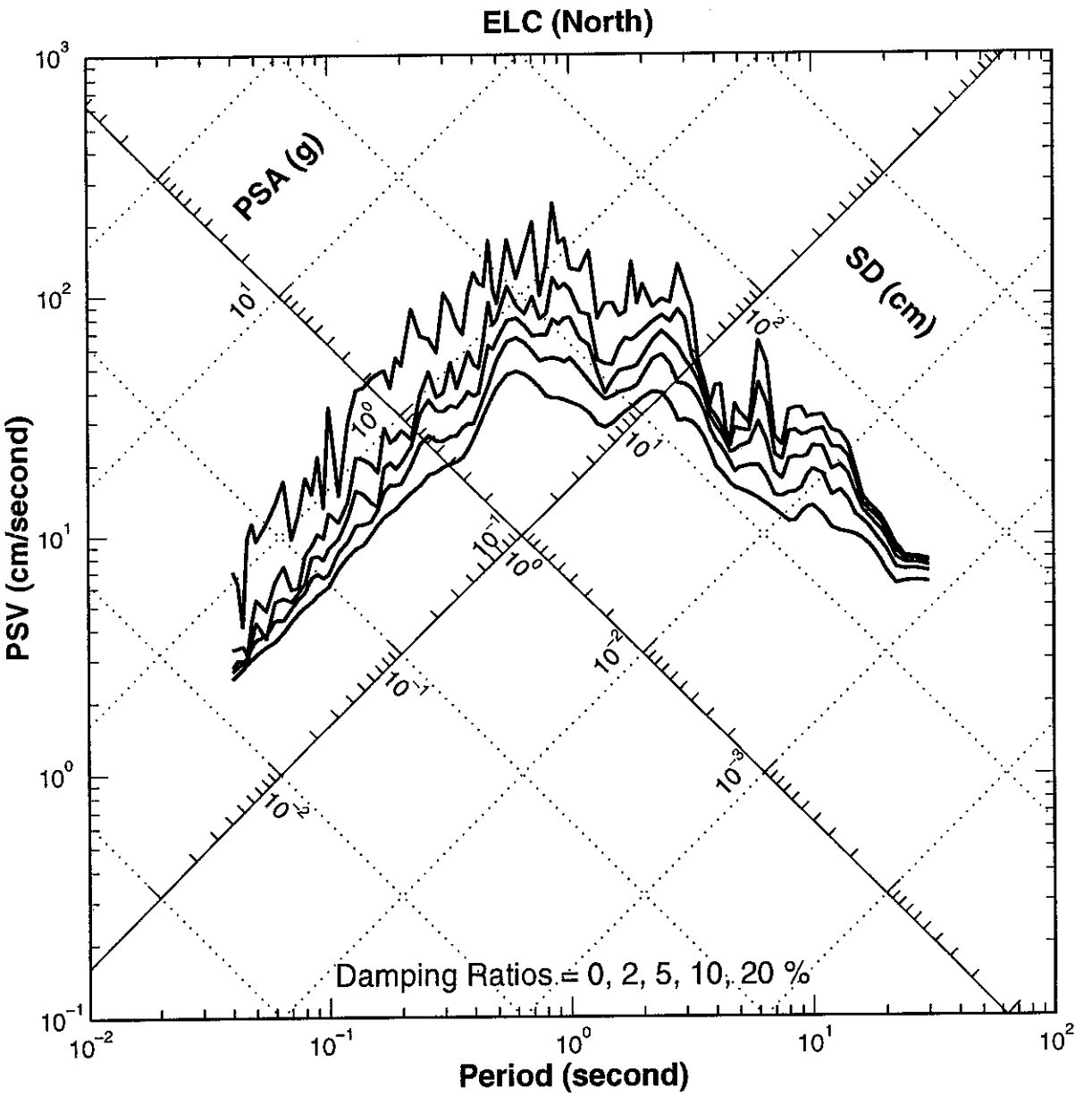

ERZ (East)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5

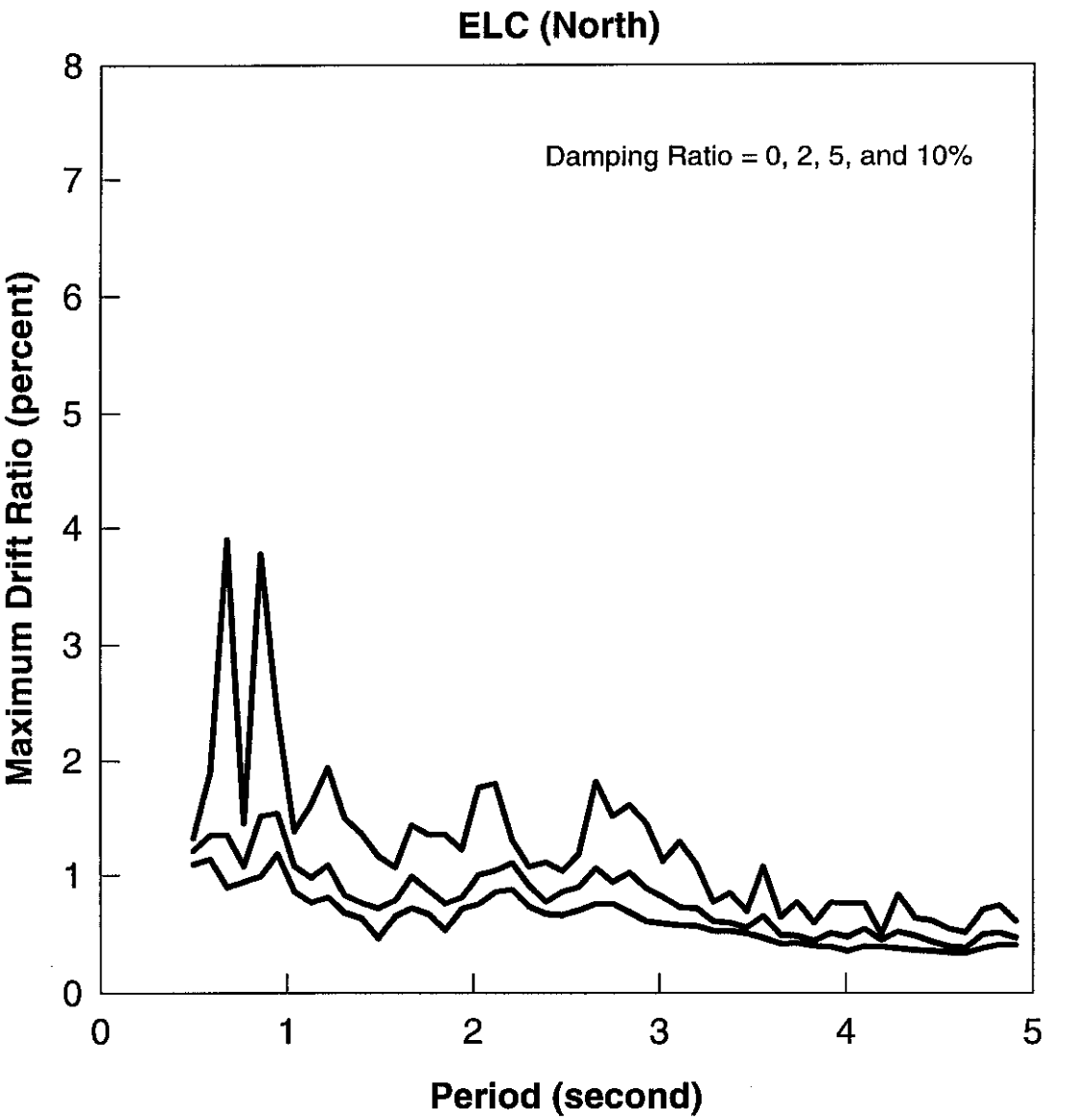

ERZ (S31W)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5

APPENDIX 1

TIME HISTORY, RESPONSE SPECTRUM, AND DRIFT DEMAND SPECTRUM OF EL CENTRO (ELC) NORTH


ELC (North)
Max = 342 cm/s/s
Acceleration (cm/s/s)
400
200
0
−200
−400
0
5
10
15
20
25
30
35
40
Max = 33 cm/s
Velocity (cm/s)
40
20
0
−20
−40
Max = 11 cm
Displacemnt (cm)
20
10
0
−10
−20
Time (second)


ELC (North)
PSA (g)
SD (cm)
PSV (cm/second)
Period (second)
Damping Ratios = 0, 2, 5, 10, 20 %


ELC (North)
Damping Ratio = 0, 2, 5, and 10%
Maximum Drift Ratio (percent)
Period (second)
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5