New Dispersion Relations for IUESIPS

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ABSTRACT

The mean dispersion constants and correlation coefficients have been updated for current IUESIPS using data taken prior to August 1991 and will be implemented in the near future. The last update to the dispersion relations, as used in production processing, was April 1988 at GSFC (Thompson 1988). The estimated error in wavelength assignments for 1991 data as a result of using the outdated coefficients can be summarized as follows. The SWP camera shows shifts of approximately 12 km/s along the spectral orders in high dispersion and slightly less than one angstrom in low. The errors along the orders in the LWR are around 3.5 km/s for high dispersion and almost 1.5 Å in low dispersion. The errors in the LWP data are not noticeable as the time dependent variations are insignificant. Spectral motions perpendicular to the dispersion are of no consequence as they are compensated for during image processing.

Introduction

Wavelength calibration (Wavecal) images are obtained once a month using Platinum-Neon (Pt-Ne) calibration lamps. Each set of wavecal images is used to derive the dispersion relations between wavelength and the line and sample position of a pixel on the camera. Wavecal images are a combination of the Pt-Ne spectrum and a Tungsten floodlamp (TFLOOD) exposure that is used to illuminate the reseau marks needed to perform the geometric correction on the raw wavecal images. The reseau marks are found on the low dispersion wavecal using a cross-correlation technique and a reseau displacement grid, which compensates for geometric distortions, is constructed and applied to both the low and high dispersion wavecal images.

The location of several emission lines, whose starting positions are determined from a set of mean dispersion constants, are found using a cross-correlation technique and combined with the laboratory measured order and wavelength position for each line. A regression analysis routine is then used to determine the dispersion relation, which equates the line and sample positions of any pixel given a wavelength and order number, for a particular wavecal image. The dispersion relations for line and sample positions are calculated by the following expressions:

$$L = B_\lambda + B_\chi m\lambda + B_\chi (m\lambda)^2 + B_\chi m + B_\chi \lambda + B_\chi m^\lambda \lambda + B_\chi m\lambda^\lambda \quad (1)$$

$$S = A_\lambda + A_\chi m\lambda + A_\chi (m\lambda)^2 + A_\chi m + A_\chi \lambda + A_\chi m^\lambda \lambda + A_\chi m\lambda^\lambda \quad (2)$$

where m is the order number and λ is the wavelength in angstroms. For low dispersion, m equals one and only the first two terms are used. The dispersion constants for each individual wavecal image are entered into a master dispersion constant file which is periodically analyzed to determine if updates to the mean dispersion constants should be made. The mean dispersion constants, as implemented in production processing, are produced by averaging together the individual terms contained in the master files. The rationale behind implementing mean dispersion constants is to eliminate discontinuities in the way IUE data is reduced by avoiding the risk of using an atypical set of constants which may differ due to unusual thermal conditions occuring at the time the wavecal exposure was taken (Turnrose, Bohlin, and Harvel 1979 and Thompson, Turnrose, and Bohlin 1981).

Spectral format shifts as a function of time and camera head amplifier temperature (THDA) are seen in the LWR and SWP cameras (the LWP camera only uses a thermal correction). These shifts are compensated for by using a set of time and temperature dependent correlation coefficients which are determined using a Gauss-Jordan matrix elimination technique and are added to the zeroeth-order term of the mean dispersion relations using the following equations:

$$W_L = W_{LL} + W_{LL}T + W_{LL}t + W_{LL}t^{\lambda} \quad (3)$$

$$W_S = W_{SL} + W_{SL}T + W_{SL}t + W_{SL}t^{\lambda} \quad (4)$$

where T is the THDA at the time of the exposure and t is the time in days since January 1, 1978 (only the first two terms are used for the LWP). A more detailed description of the wavecal process can be found in the IUE Image Processing Manual (Turnrose and Thompson 1984).

Wavelength Calibration Software Rehosting Status

The conversion of Sigma 9 wavecal software, as used in current IUESIPS production processing, to VAX MIDAS/FORTRAN format and testing of the high dispersion wavecal processing software has been completed. Occasional discrepancies still exist between the individual dispersion constants for high dispersion wavecal images, as derived by the VAX code, when compared with their Sigma 9 counterpart. These differences are rendered negligible, however, when the individual dispersion constants are averaged together to produce a set of mean dispersion constants. The line and sample positions, as determined from each set (Sigma 9 and VAX) of mean dispersion constants, differ by no more than one-tenth of a pixel. Both high and low dispersion wavecal images are now processed on the VAX computer and the master dispersion constant file is automatically updated. All remaining items that were pending from our previous reports (Oliversen and Dunn, 1990 and Garhart and Oliversen, 1991) have been successfully converted and the current processing backlog of wavecals has been eliminated. The master dispersion constant file has been analyzed and updated values for the mean dispersion constants and the time and temperature dependent coefficients have been generated.

Implementation of New Dispersion Constants and Correlation Coefficients

New mean dispersion constants and time and temperature dependent coefficients have been determined for all three cameras. The previous set of dispersion constants and coefficients were derived using wavecal data obtained prior to September 1987 (Thompson 1988). This new analysis is generated from wavecals taken prior to August 1991 and does not include the updated line library (Bushouse 1991) or the new form of the dispersion relation (Smith 1990). These issues will be addressed only in the Final Archive software.

The figures in Table 1 show various statistics concerning the master dispersion constant database and the standard deviations before and after the time and temperature corrections are applied. The new mean dispersion constants and correlation coefficients are listed in Table 2 and are used in Equations 1 through 4 to determine the line and sample positions of pixels in geometrically-corrected space. A comparison of various combinations of time and/or temperature fits are displayed in Table 3. One sees that by using the combination of a temperature and second-order time correlation for the LWR and SWP data substantially reduces the RMS errors when compared with other types of fits, however, there is no great improvement over using this type of fit for the LWP camera versus using a simple temperature dependent fit.

Systematic wavelength errors, which increase with time, can occur as a result of using outdated correlation coefficients. The plots in Figures 1 through 12 show the high and low dispersion wavecal data fitted using both the old and new set of correlation coefficients. The 'x' symbols, in each case, represent the raw scatter about the mean in the position of a single wavelength assignment as a function of time. The values are generated by calculating line and sample positions using each individual set of dispersion constants in the master dispersion constant file, converting them to positions perpendicular and along the dispersion, and subtracting the mean. The scatter seen in the data is also a good example of why mean dispersion constants are used. The use of dispersion constants derived from individual wavecals would introduce serious discontinuities in the determination of line and sample positions for a given pixel from month to month. The '+' symbols, connected by a jagged line, represent the data after applying a first-order THDA dependent correction. The curved line represents the correction made by applying a second-order time dependent fit to the temperature corrected data (the LWP uses a first-order time fit). Any deviation of the smooth line from the jagged one represents an error in the correction that was applied, as one would expect from using an outmoded set of correlation coefficients.

The errors that occur from using the previous set of coefficients are not very noticeable in the LWP data (Figures 1 and 3) since the time dependent variations are insignificant. The LWR and SWP data (Figures 5, 7, 9, and 11) exhibit more pronounced time dependent deviations starting around 1988 (*i.e.* about the time the previous set of correlation coefficients were implemented). The errors introduced to LWR data taken in 1991 as a result of using the outdated correction coefficients amount to a shift of approximately half a pixel along and perpendicular to the dispersion (spatial direction) in both high and low dispersion. This corresponds to a wavelength error of about 1.5 Å for low dispersion data and around 3.5 km/s for high dispersion data. Spectral motions perpendicular to the dispersion are inconsequential as these shifts are compensated for during the spectral registration process, while spectral motion along the dispersion direction results in a wavelength error. The SWP errors for 1991 data result in a shift of around 1.5 pixels or approximately 12 km/s along the high dispersion. The SWP low dispersion shifts along the dispersion direction result in an error of approximately 0.5 pixel or 1 Å.

Figures 13 through 15 show the difference in calculated pixel positions for each wavelength in the line library using the old and new mean dispersion constants. The diamond shaped symbols represent locations from the old set of means and the lines point towards the shifted locations determined from the new set of mean dispersion constants. These spectral motions are due mostly to the time dependent shifts and are independent of wavelength and dispersion (Thompson, 1988).

The calibration group recommends that the new mean dispersion constants and correlation coefficients be implemented into production processing (IUESIPS) and that we should continue to use a simple THDA correction for the LWP camera.

References

Bushouse, H. 1991, *IUE NASA Newsletter*, **45**, 46.

Garhart, M., and Oliversen, N. 1991, *Record of the IUE Three-Agency Coordination Committee*, January 1991, E-5.

Oliversen, N., and Dunn, N. 1990, *Record of the IUE Three-Agency Coordination Committee*, March 1990, F-41.

Smith, M. 1990, *Record of the IUE Three-Agency Coordination Committee*, March 1990, B-51.

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Thompson, R., Turnrose, B., and Bohlin, R. 1981, *IUE NASA Newsletter*, **15**, 8.

Turnrose, B., Bohlin, R., and Harvel, C. 1979, *IUE NASA Newsletter*, **7**, 17.

Turnrose, B., and Thompson, R. 1984, *IUE Image Processing Information Manual*, Version 2.0 (New Software), CSC/TM-84/6058

Table 1.

Dispersion Constant Statistics

Low Dispersion

	LWP	LWR	SWP
No. of D.C.	176	182	231
Mean Time	1986.11	1984.11	1984.65
Start Time	1980.46	1978.54	1978.75
End Time	1991.50	1991.50	1991.50
Mean THDA (°C)	9.4	13.3	9.0
Min. THDA	5.5	8.8	5.1
Max. THDA	13.8	18.3	13.2
Raw Scatter (in pixels)			
Parallel	0.41	0.37	1.07
Perpendicular	0.70	1.78	1.15
Scatter after correction	[THDA only]	[THDA & $Time^2$]	[THDA & $Time^2$]
Parallel	0.31	0.27	0.22
Perpendicular	0.40	0.41	0.32

High Dispersion

	LWP	LWR	SWP
No. of D.C.	174	180	232
Mean Time	1986.11	1984.18	1984.63
Start Time	1980.46	1978.75	1978.70
End Time	1991.50	1991.50	1991.50
Mean THDA (°C)	9.6	13.6	9.1
Min. THDA	6.2	9.5	5.1
Max. THDA	14.2	18.3	13.2
Raw Scatter (in pixels)			
Parallel	0.72	1.48	1.22
Perpendicular	0.38	0.31	0.59
Scatter after correction	[THDA only]	[THDA & $Time^2$]	[THDA & $Time^2$]
Parallel	0.35	0.39	0.28
Perpendicular	0.21	0.23	0.17

Table 2.

Mean Dispersion Constants and Correlation Coefficients
For the Small Aperture (1 of 3)

Dispersion Constants	**LWP Low**	**LWP High**
$A_1 =$	0.1046928512500000E+04	0.4452096859367816E+04
$A_2 =$	-.2868053995454545E+00	-.1618401720114943E+00
$A_3 =$		0.6369592363448276E-06
$A_4 =$		0.1815022751724138E+02
$A_5 =$		0.4481368490804598E+00
$A_6 =$		-.7822886651130460E-04
$A_7 =$		-.3167913802172414E-05
$B_1 =$	-.2718023847159091E+03	0.1459818377448276E+04
$B_2 =$	0.2464567132954546E+00	-.1503258216666667E+00
$B_3 =$		0.6188011206954023E-06
$B_4 =$		0.2466516535183908E+00
$B_5 =$		0.3129906960919540E+00
$B_6 =$		-.9947589404022989E-06
$B_7 =$		-.2881194847298850E-06

Correlation Coefficients

$W_{S1} =$	-.1047593320691922E+01	-.1011049108443029E+01
$W_{S2} =$	0.1116900321651377E+00	0.1050544847762751E+00
$W_{L1} =$	-.3614478948195158E+01	-.4445930660750616E+01
$W_{L2} =$	0.3853606757606024E+00	0.4619607010340653E+00

Table 2.

Mean Dispersion Constants and Correlation Coefficients
For the Small Aperture (2 of 3)

Dispersion Constants	**LWR Low**	**LWR High**
$A_1 =$	-.2999126620329670E+03	-.4563664583664444E+04
$A_2 =$	0.3022846544505495E+00	0.1445254945555556E+00
$A_3 =$		-.5462139911611111E-06
$A_4 =$		0.3657639584555556E-01
$A_5 =$		0.2819878819444444E+00
$A_6 =$		-.1001402237777778E-06
$A_7 =$		0.8936630608333334E-07
$B_1 =$	-.2641631525274725E+03	0.1565607667777778E+05
$B_2 =$	0.2257191779120879E+00	-.2796044601666667E+00
$B_3 =$		0.9124395084055556E-06
$B_4 =$		0.5875851539500000E-01
$B_5 =$		0.2258988701111111E+00
$B_6 =$		-.2953719577777778E-08
$B_7 =$		0.5378108294444445E-08
Correlation Coefficients		
$W_{S1} =$	0.6005056062566139E+01	0.5964766460976751E+01
$W_{S2} =$	-.2534052064615562E+00	-.3011695430480186E+00
$W_{S3} =$	-.1877802764857402E-02	-.1345644813630571E-02
$W_{S4} =$	0.2307343524994781E-06	0.1724383812510869E-06
$W_{L1} =$	-.9151681144506006E+01	-.9038758436185195E+01
$W_{L2} =$	0.4843478357791913E+00	0.5402949562939730E+00
$W_{L3} =$	0.1994950048334771E-02	0.1174370278388261E-02
$W_{L4} =$	-.2584920509527238E-06	-.1429923415856673E-06

Table 2.

Mean Dispersion Constants and Correlation Coefficients
For the Small Aperture (3 of 3)

Dispersion Constants	**SWP Low**	**SWP High**
$A_1 =$	0.9846908945021645E+03	-.1139613663146552E+03
$A_2 =$	-.4666239731168831E+00	-.1620278179741379E+00
$A_3 =$		0.1237148406250000E-05
$A_4 =$		0.1511115127495690E+00
$A_5 =$		-.4383054155603448E+00
$A_6 =$		-.1078180255008621E-05
$A_7 =$		-.2091483420086207E-06
$B_1 =$	-.2630243495670995E+03	-.7332319083620690E+04
$B_2 =$	0.3761272301731601E+00	-.1156287233021552E+00
$B_3 =$		0.1212566067586207E-05
$B_4 =$		-.9613544402500000E-01
$B_5 =$		0.3915029520991379E+00
$B_6 =$		0.7036754446465517E-06
$B_7 =$		-.1210524664698276E-06
Correlation Coefficients		
$W_{S1} =$	-.4203255739712417E+01	-.3546786114440202E+01
$W_{S2} =$	-.5832055168594793E-03	0.5935536772984714E-01
$W_{S3} =$	0.2730208713091088E-02	0.1924154463303553E-02
$W_{S4} =$	-.3243680685124550E-06	-.2221021526822672E-06
$W_{L1} =$	-.1936812288694771E+01	-.3361595365660100E+01
$W_{L2} =$	0.1550433544902592E+00	0.2330510265487091E+00
$W_{L3} =$	0.5003654263156550E-03	0.8163589023837562E-03
$W_{L4} =$	-.9106206419083089E-07	-.1001668887693387E-06

Table 3.

Total RMS Scatter (in pixels) for Various Corrections to the Mean Dispersion Constants

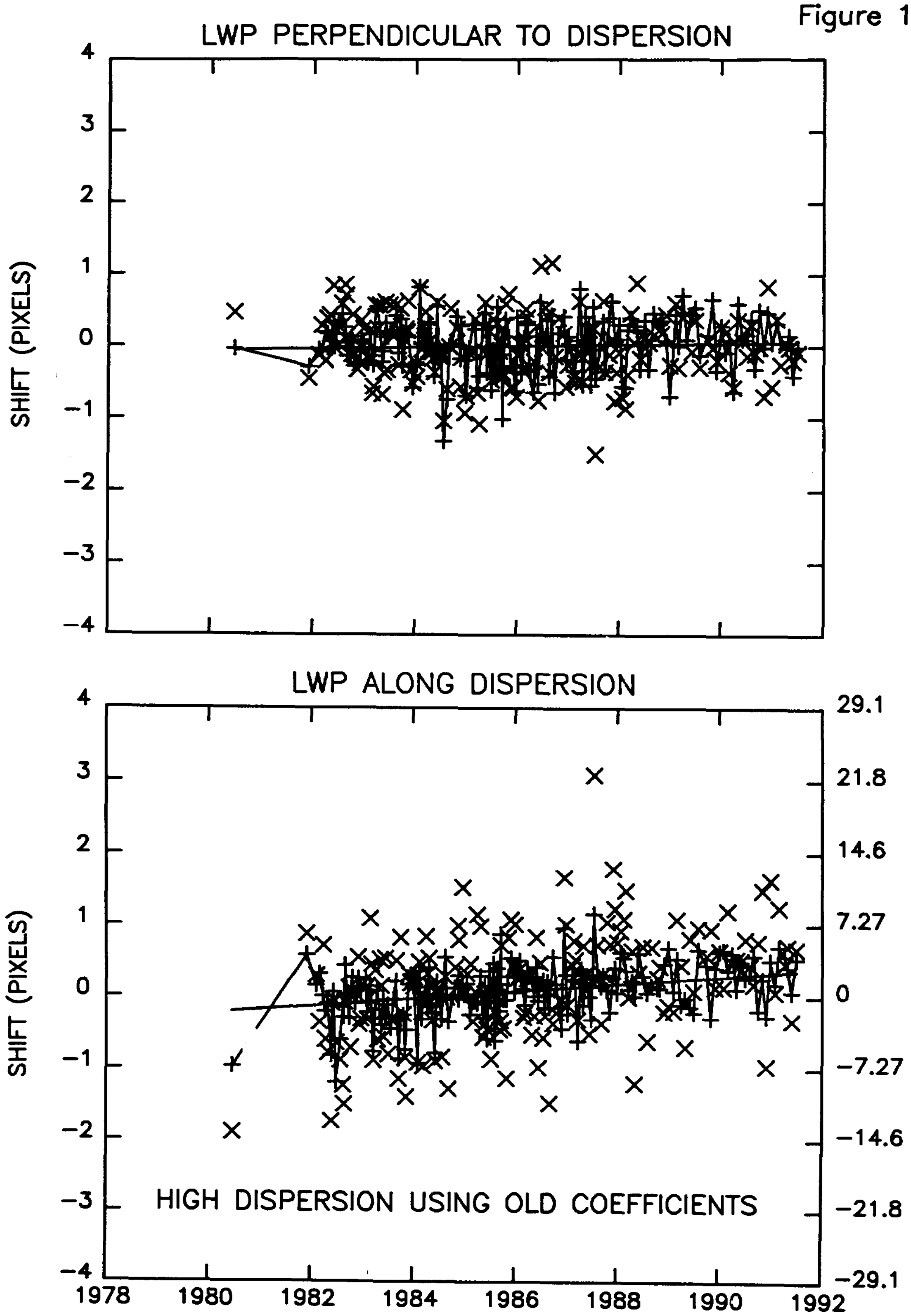
Low Dispersion

	LWP	LWR	SWP
Raw Scatter	0.81	1.82	1.57
1st Order Time	0.71	1.19	0.71
1st Order THDA	0.51	1.53	1.46
THDA and 1st Order Time	0.42	0.76	0.65
THDA and 2nd Order Time	0.42	0.49	0.39
No. of Points	176	182	231

High Dispersion

	LWP	LWR	SWP
Raw Scatter	0.81	1.51	1.35
1st Order Time	0.77	1.16	0.66
1st Order THDA	0.41	1.03	1.15
THDA and 1st Order Time	0.38	0.58	0.41
THDA and 2nd Order Time	0.38	0.46	0.33
No. of Points	174	180	232

Figure 1



LWP PERPENDICULAR TO DISPERSION
SHIFT (PIXELS)
4
3
2
1
0
−1
−2
−3
−4
LWP ALONG DISPERSION
SHIFT (PIXELS)
VELOCITY (KM/S)
29.1
21.8
14.6
7.27
0
−7.27
−14.6
−21.8
−29.1
HIGH DISPERSION USING OLD COEFFICIENTS
1978
1980
1982
1984
1986
1988
1990
1992

Figure 2

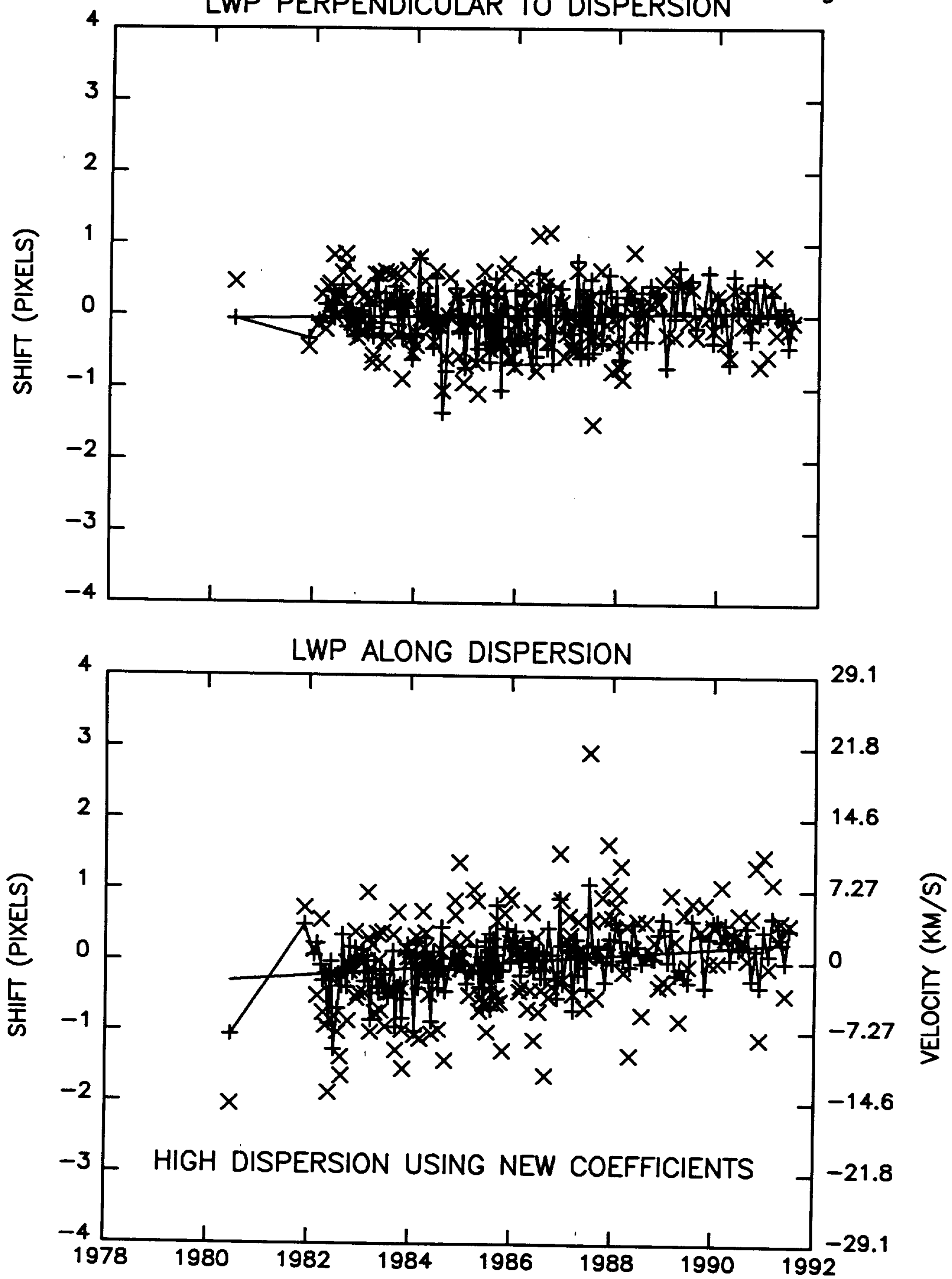

LWP PERPENDICULAR TO DISPERSION
SHIFT (PIXELS)
4
3
2
1
0
−1
−2
−3
−4
LWP ALONG DISPERSION
SHIFT (PIXELS)
VELOCITY (KM/S)
29.1
21.8
14.6
7.27
0
−7.27
−14.6
−21.8
−29.1
HIGH DISPERSION USING NEW COEFFICIENTS
1978
1980
1982
1984
1986
1988
1990
1992

Figure 3

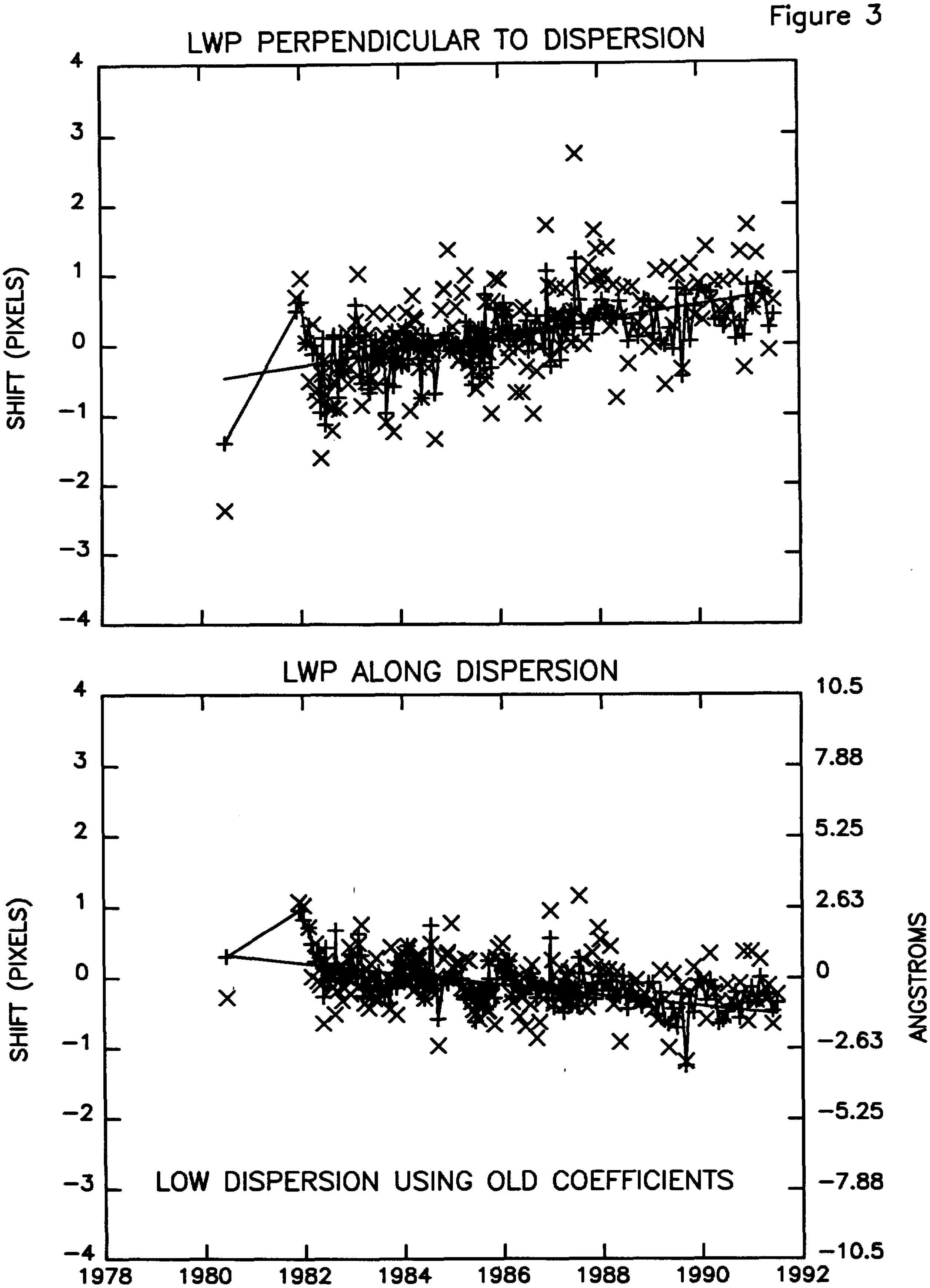
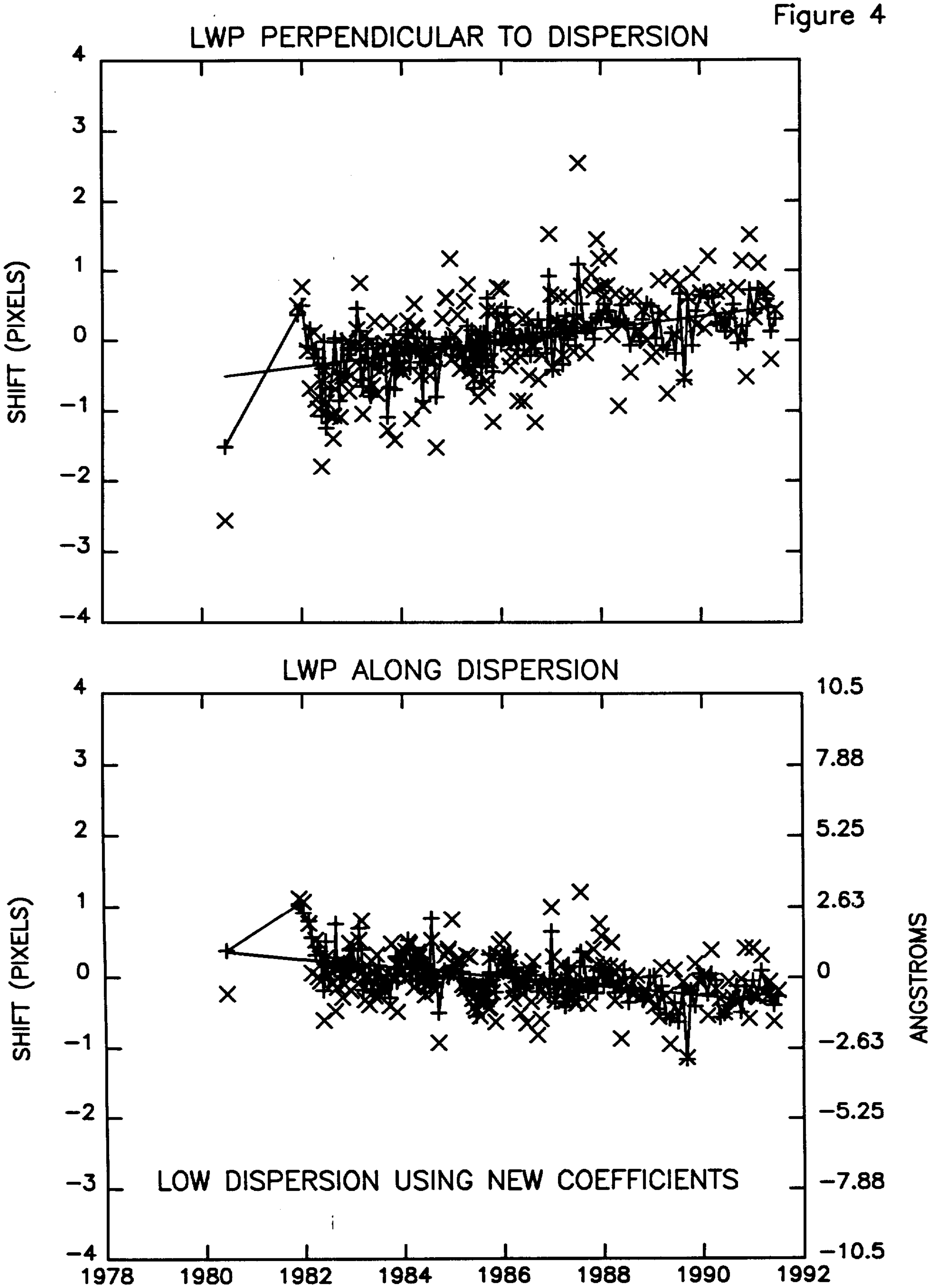
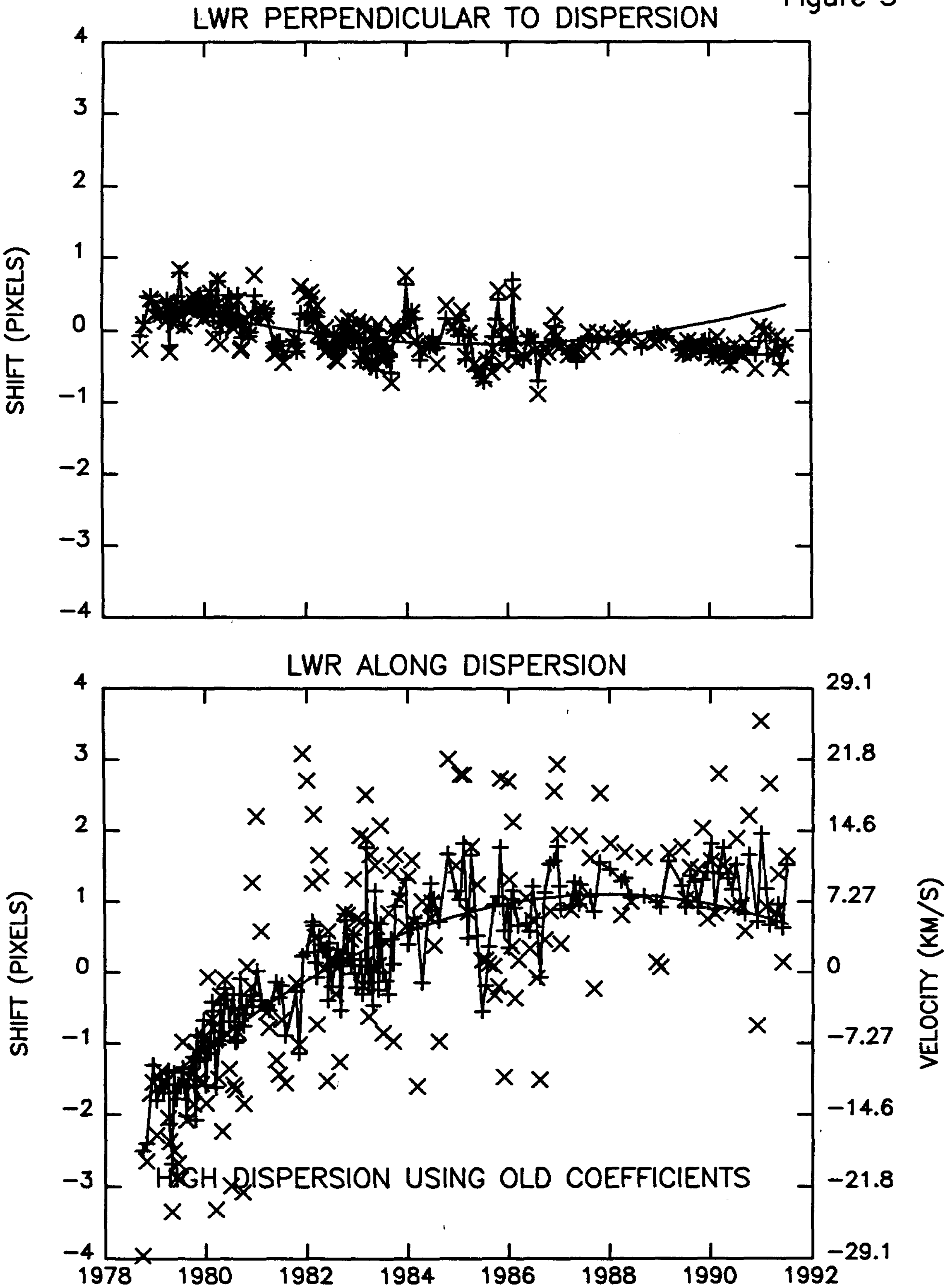

LWP PERPENDICULAR TO DISPERSION
SHIFT (PIXELS)
4
3
2
1
0
−1
−2
−3
−4
LWP ALONG DISPERSION
SHIFT (PIXELS)
ANGSTROMS
10.5
7.88
5.25
2.63
0
−2.63
−5.25
−7.88
−10.5
LOW DISPERSION USING OLD COEFFICIENTS
1978
1980
1982
1984
1986
1988
1990
1992

Figure 4



LWP PERPENDICULAR TO DISPERSION
SHIFT (PIXELS)
4
3
2
1
0
−1
−2
−3
−4
LWP ALONG DISPERSION
SHIFT (PIXELS)
ANGSTROMS
10.5
7.88
5.25
2.63
0
−2.63
−5.25
−7.88
−10.5
LOW DISPERSION USING NEW COEFFICIENTS
1978
1980
1982
1984
1986
1988
1990
1992

Figure 5



LWR PERPENDICULAR TO DISPERSION
SHIFT (PIXELS)
4
3
2
1
0
−1
−2
−3
−4
LWR ALONG DISPERSION
SHIFT (PIXELS)
VELOCITY (KM/S)
29.1
21.8
14.6
7.27
0
−7.27
−14.6
−21.8
−29.1
HIGH DISPERSION USING OLD COEFFICIENTS
1978
1980
1982
1984
1986
1988
1990
1992

Figure 6

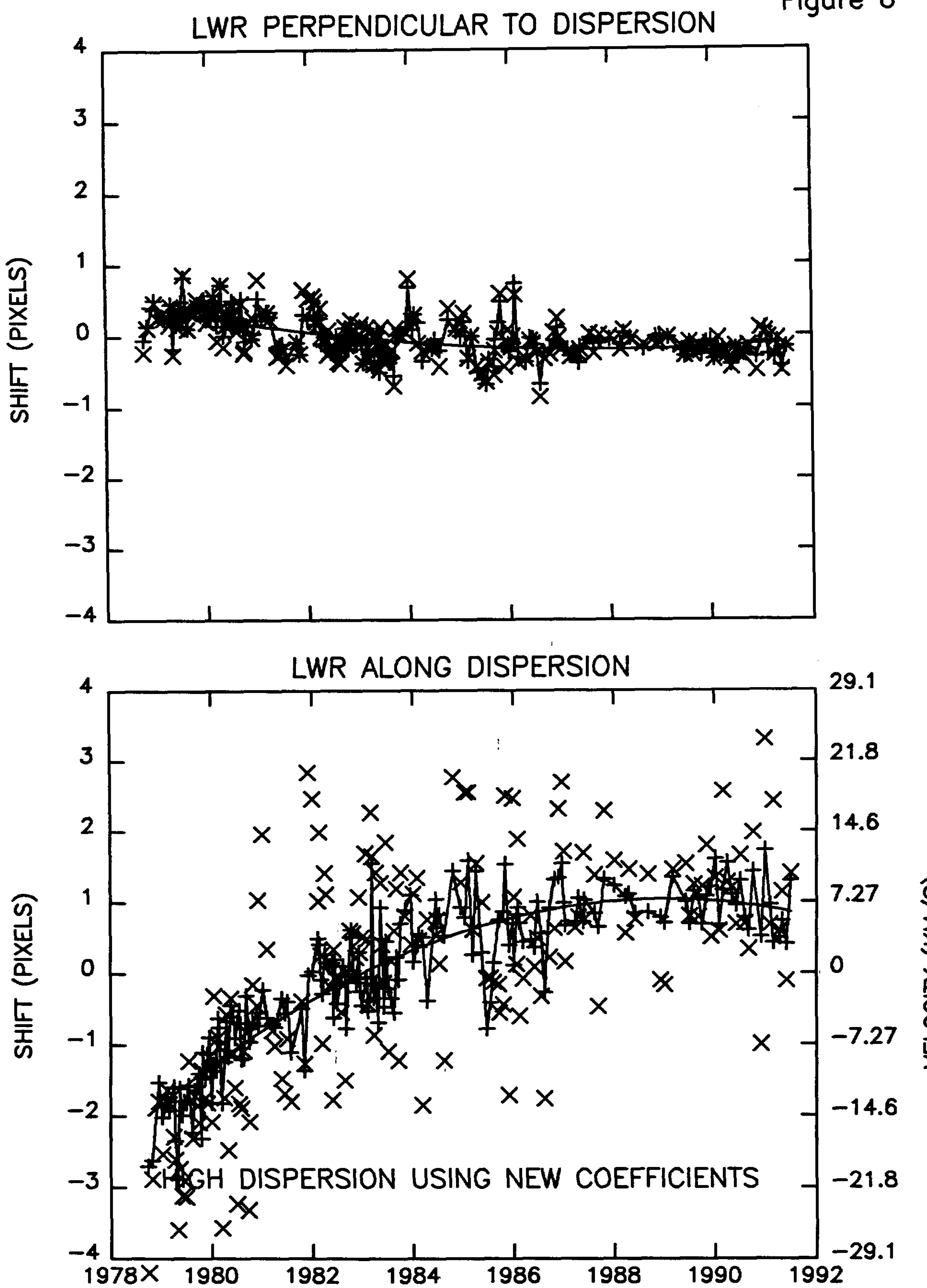

LWR PERPENDICULAR TO DISPERSION
SHIFT (PIXELS)
4
3
2
1
0
−1
−2
−3
−4
LWR ALONG DISPERSION
SHIFT (PIXELS)
VELOCITY (KM/S)
29.1
21.8
14.6
7.27
0
−7.27
−14.6
−21.8
−29.1
HIGH DISPERSION USING NEW COEFFICIENTS
1978
1980
1982
1984
1986
1988
1990
1992

Figure 7

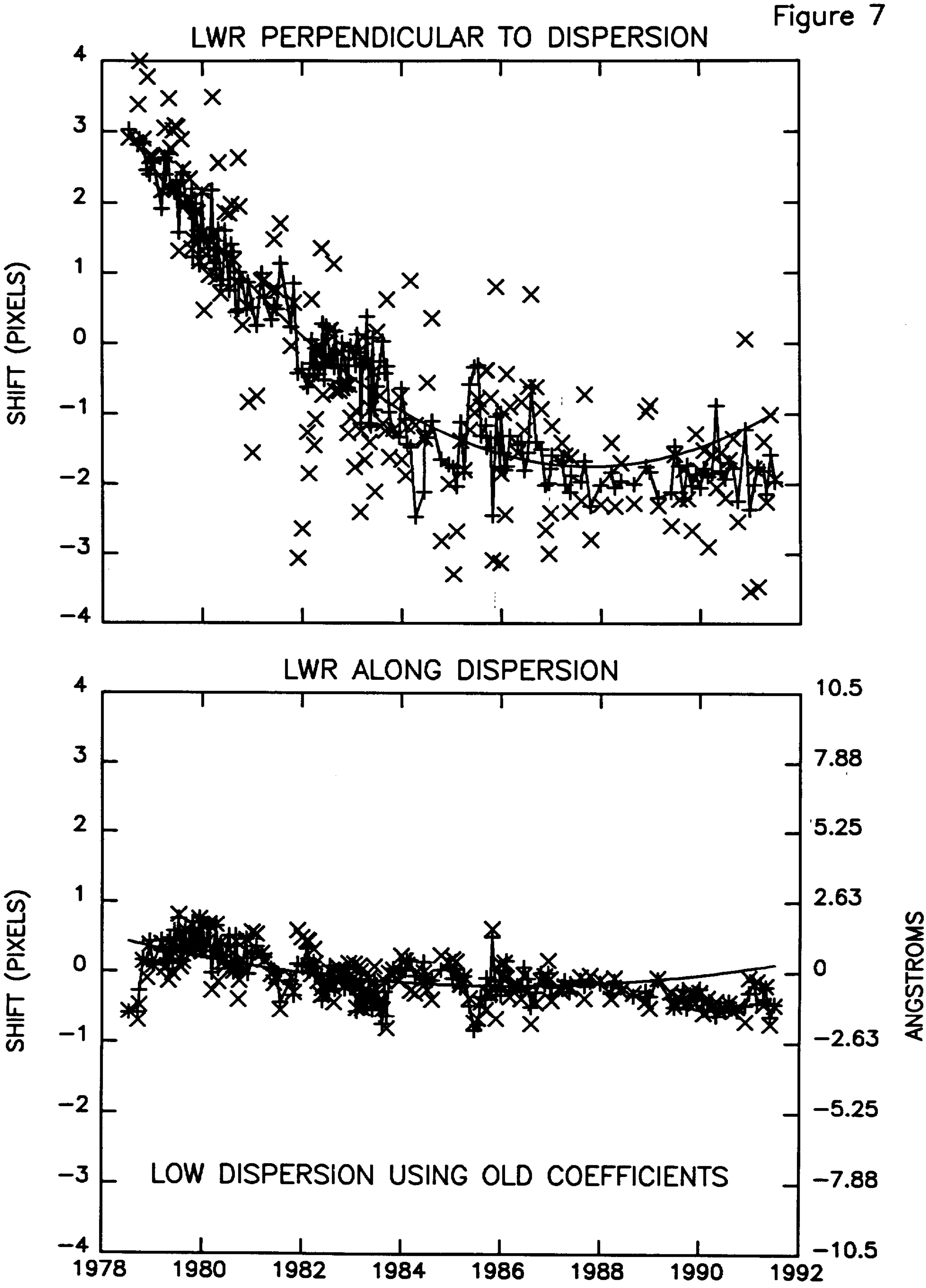

LWR PERPENDICULAR TO DISPERSION
SHIFT (PIXELS)
4
3
2
1
0
−1
−2
−3
−4
LWR ALONG DISPERSION
SHIFT (PIXELS)
ANGSTROMS
10.5
7.88
5.25
2.63
0
−2.63
−5.25
−7.88
−10.5
LOW DISPERSION USING OLD COEFFICIENTS
1978
1980
1982
1984
1986
1988
1990
1992

Figure 8

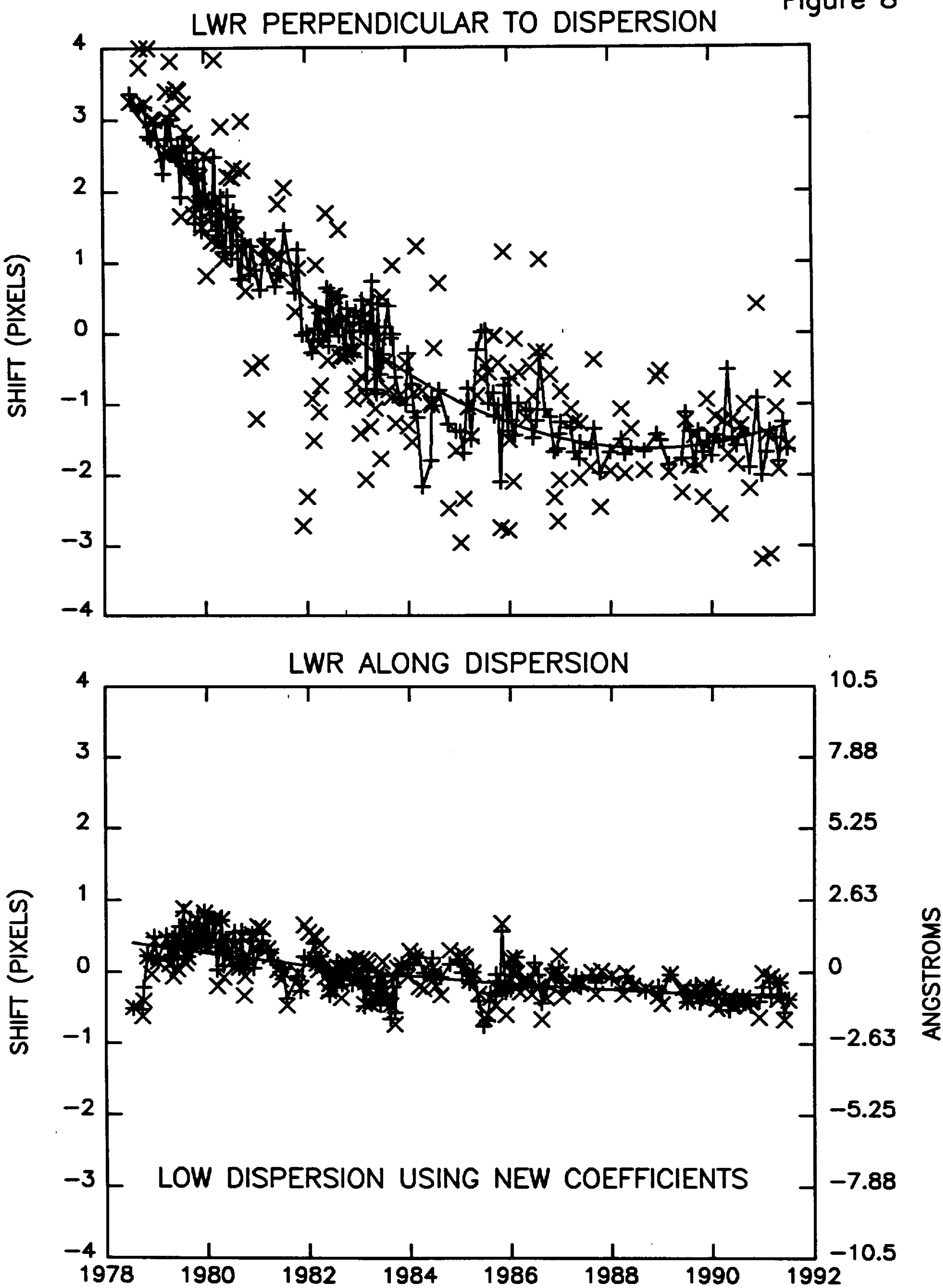

LWR PERPENDICULAR TO DISPERSION
SHIFT (PIXELS)
4
3
2
1
0
−1
−2
−3
−4
LWR ALONG DISPERSION
SHIFT (PIXELS)
ANGSTROMS
10.5
7.88
5.25
2.63
0
−2.63
−5.25
−7.88
−10.5
LOW DISPERSION USING NEW COEFFICIENTS
1978
1980
1982
1984
1986
1988
1990
1992

Figure 9

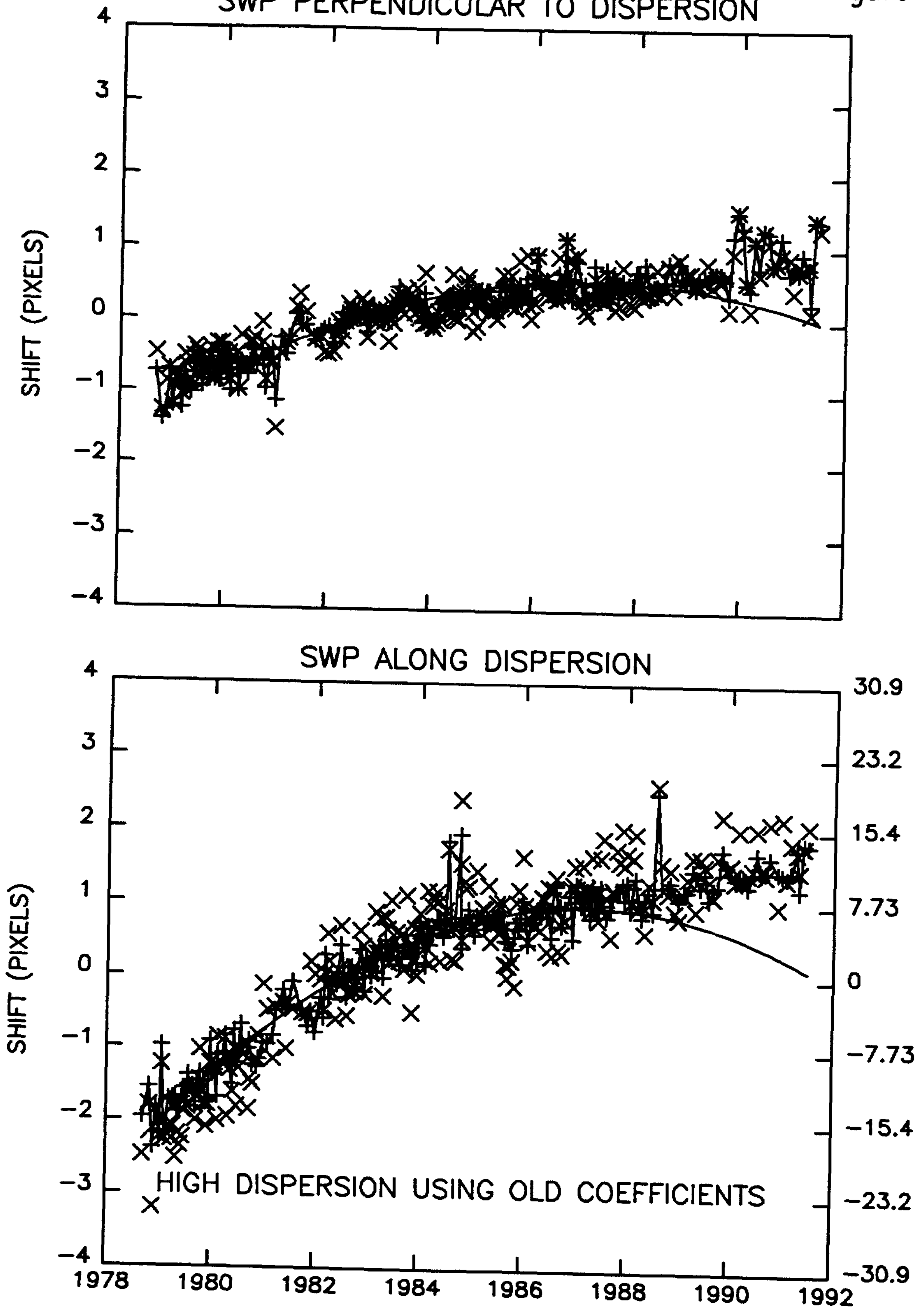
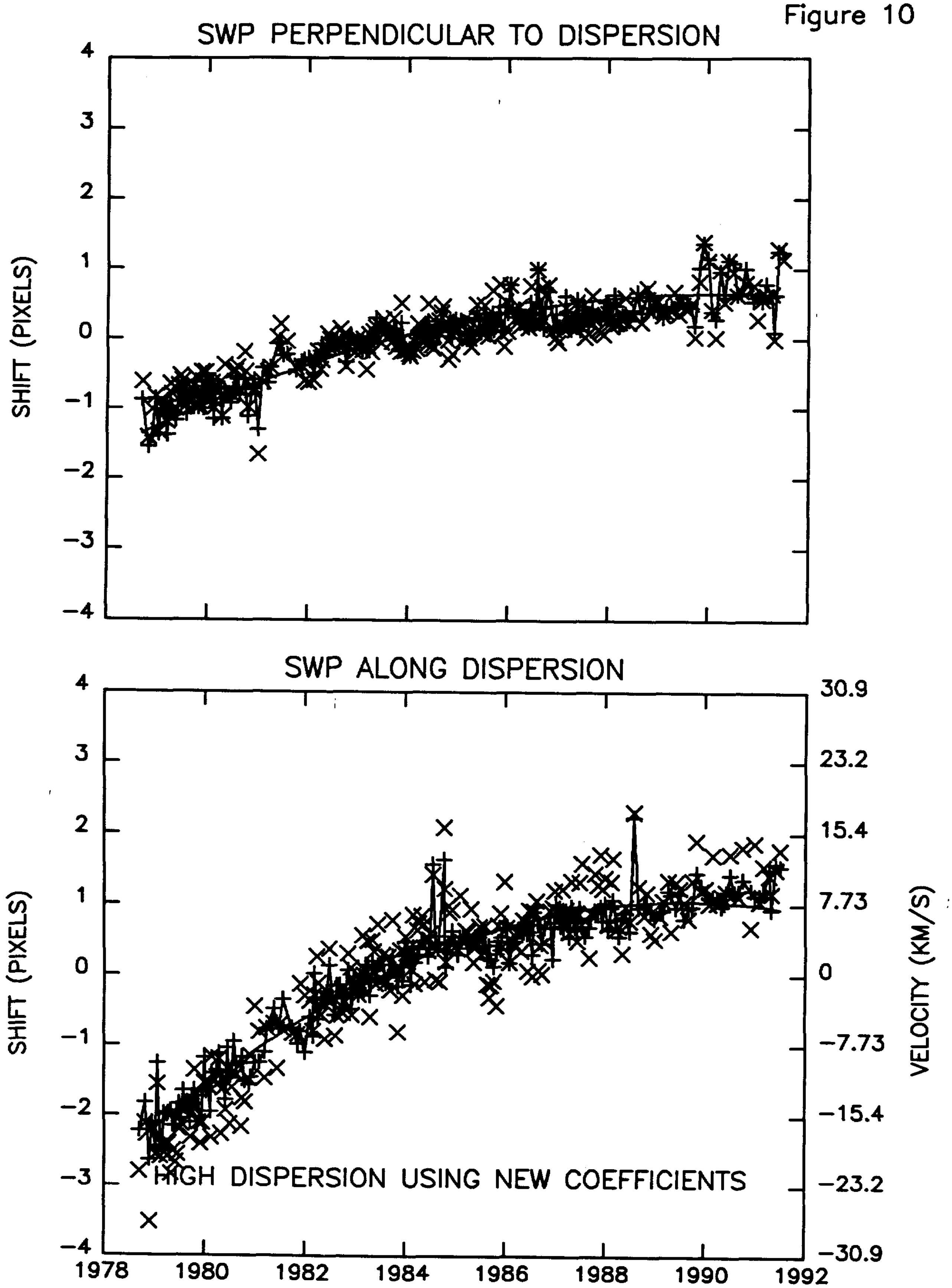

SWP PERPENDICULAR TO DISPERSION
SHIFT (PIXELS)
4
3
2
1
0
−1
−2
−3
−4
SWP ALONG DISPERSION
SHIFT (PIXELS)
4
3
2
1
0
−1
−2
−3
−4
VELOCITY (KM/S)
30.9
23.2
15.4
7.73
0
−7.73
−15.4
−23.2
−30.9
HIGH DISPERSION USING OLD COEFFICIENTS
1978
1980
1982
1984
1986
1988
1990
1992

Figure 10


SWP PERPENDICULAR TO DISPERSION
SHIFT (PIXELS)
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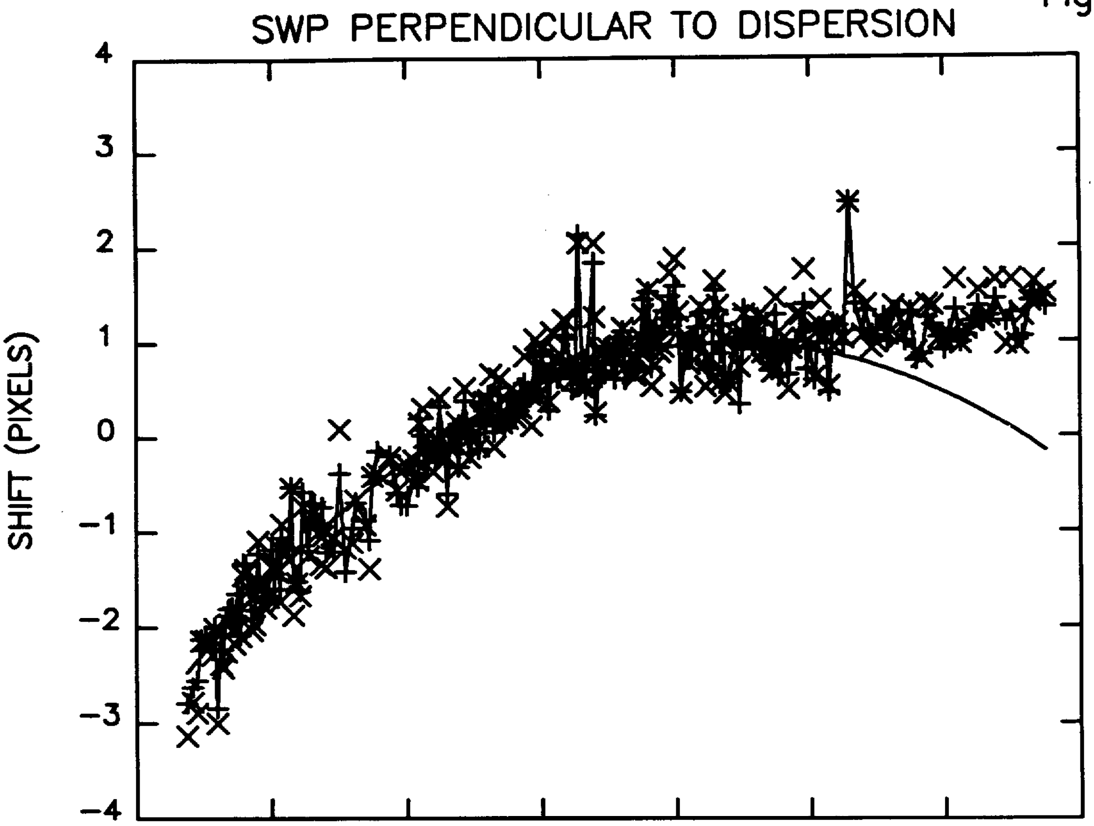
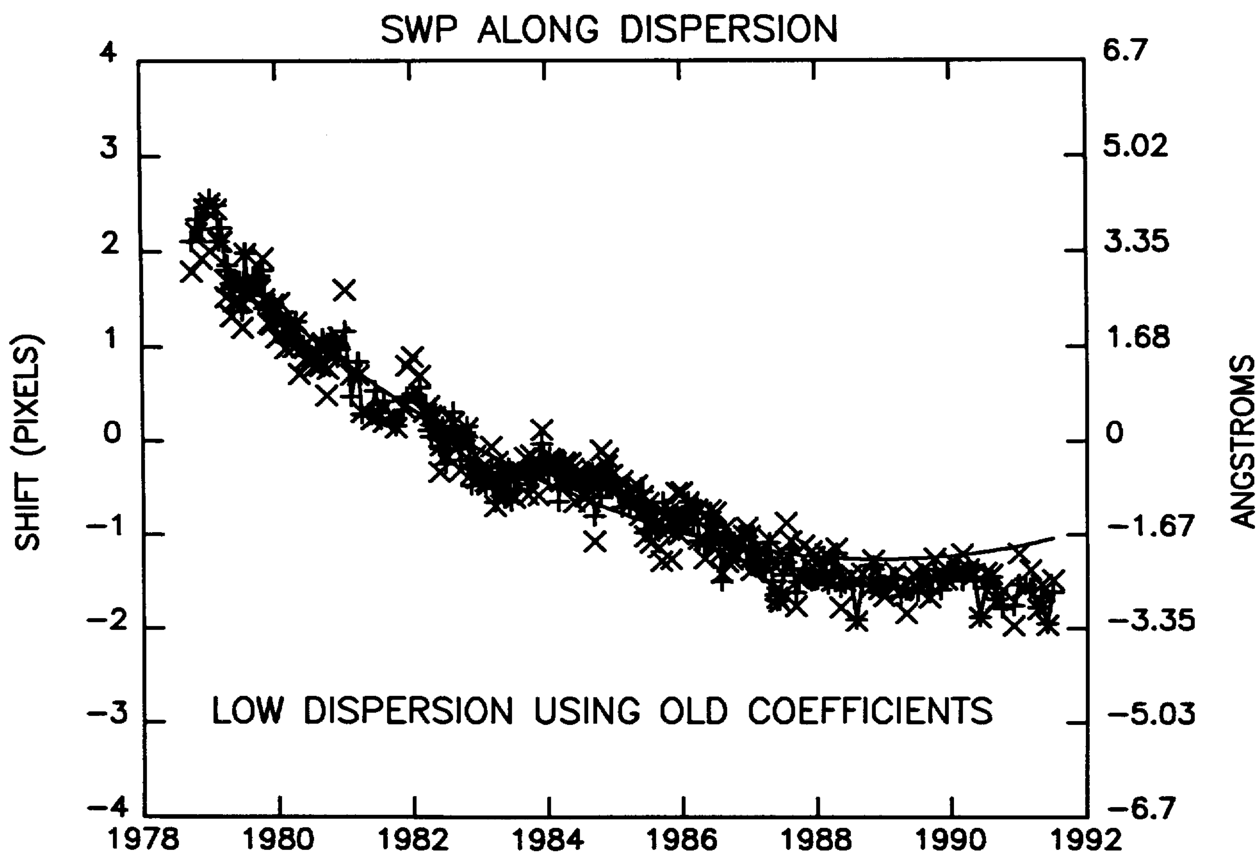
3
2
1
0
−1
−2
−3
−4
SWP ALONG DISPERSION
SHIFT (PIXELS)
VELOCITY (KM/S)
30.9
23.2
15.4
7.73
0
−7.73
−15.4
−23.2
−30.9
HIGH DISPERSION USING NEW COEFFICIENTS
1978
1980
1982
1984
1986
1988
1990
1992

Figure 11

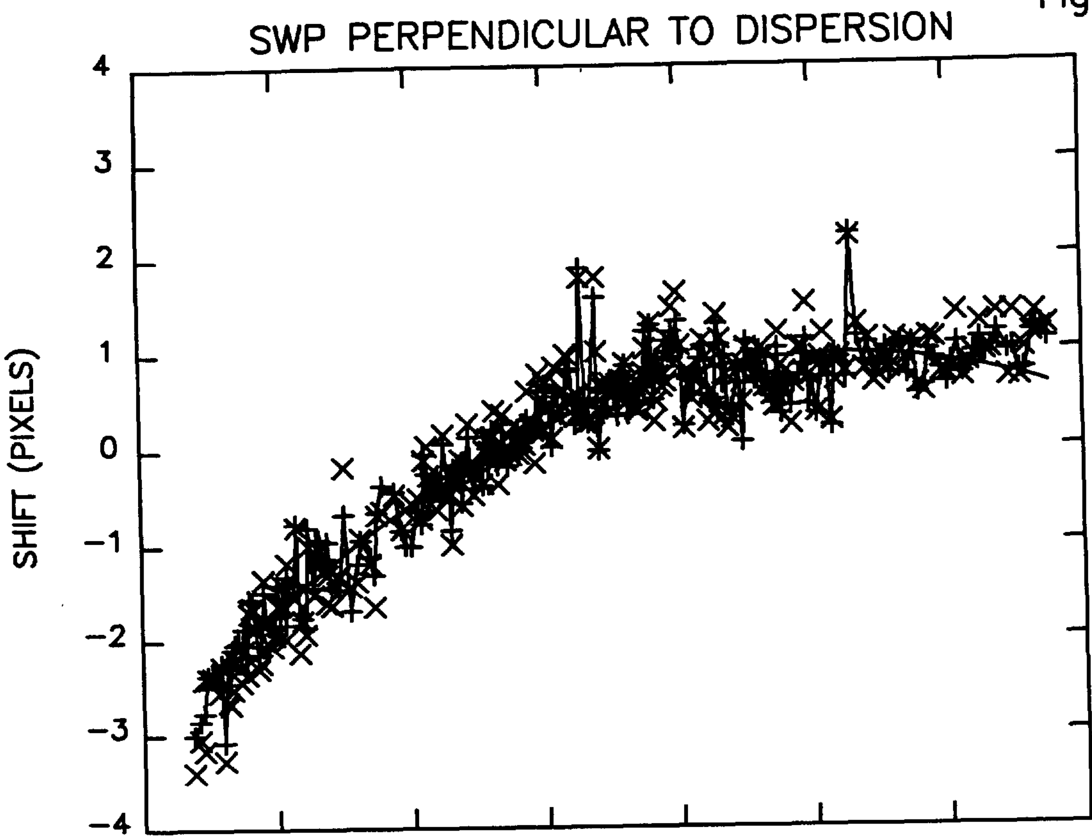


SWP PERPENDICULAR TO DISPERSION
SHIFT (PIXELS)
4
3
2
1
0
−1
−2
−3
−4

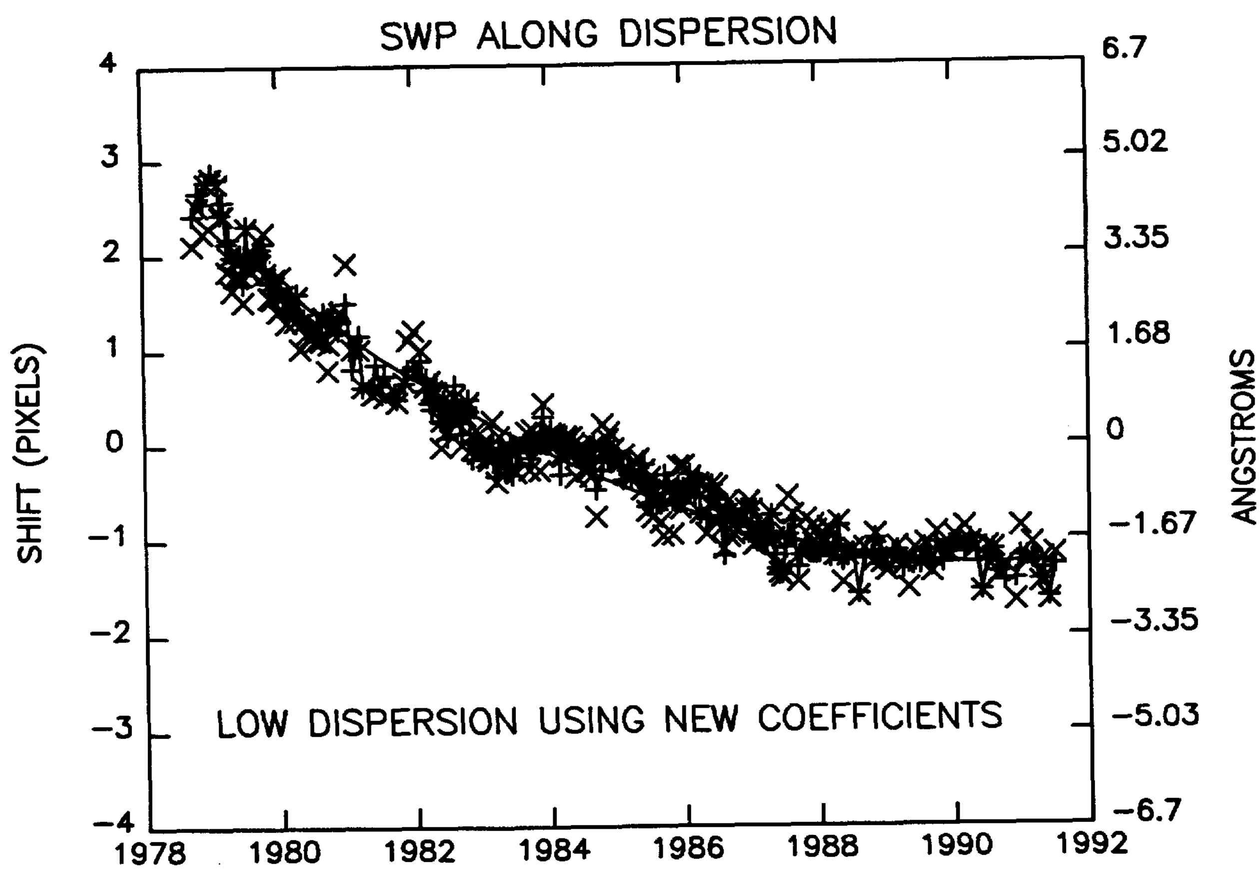


SWP ALONG DISPERSION
SHIFT (PIXELS)
ANGSTROMS
4
3
2
1
0
−1
−2
−3
−4
6.7
5.02
3.35
1.68
0
−1.67
−3.35
−5.03
−6.7
LOW DISPERSION USING OLD COEFFICIENTS
1978
1980
1982
1984
1986
1988
1990
1992

Figure 12



SWP PERPENDICULAR TO DISPERSION
SHIFT (PIXELS)
4
3
2
1
0
−1
−2
−3
−4



SWP ALONG DISPERSION
SHIFT (PIXELS)
4
3
2
1
0
−1
−2
−3
−4
6.7
5.02
3.35
1.68
0
−1.67
−3.35
−5.03
−6.7
ANGSTROMS
LOW DISPERSION USING NEW COEFFICIENTS
1978
1980
1982
1984
1986
1988
1990
1992

Figure 13

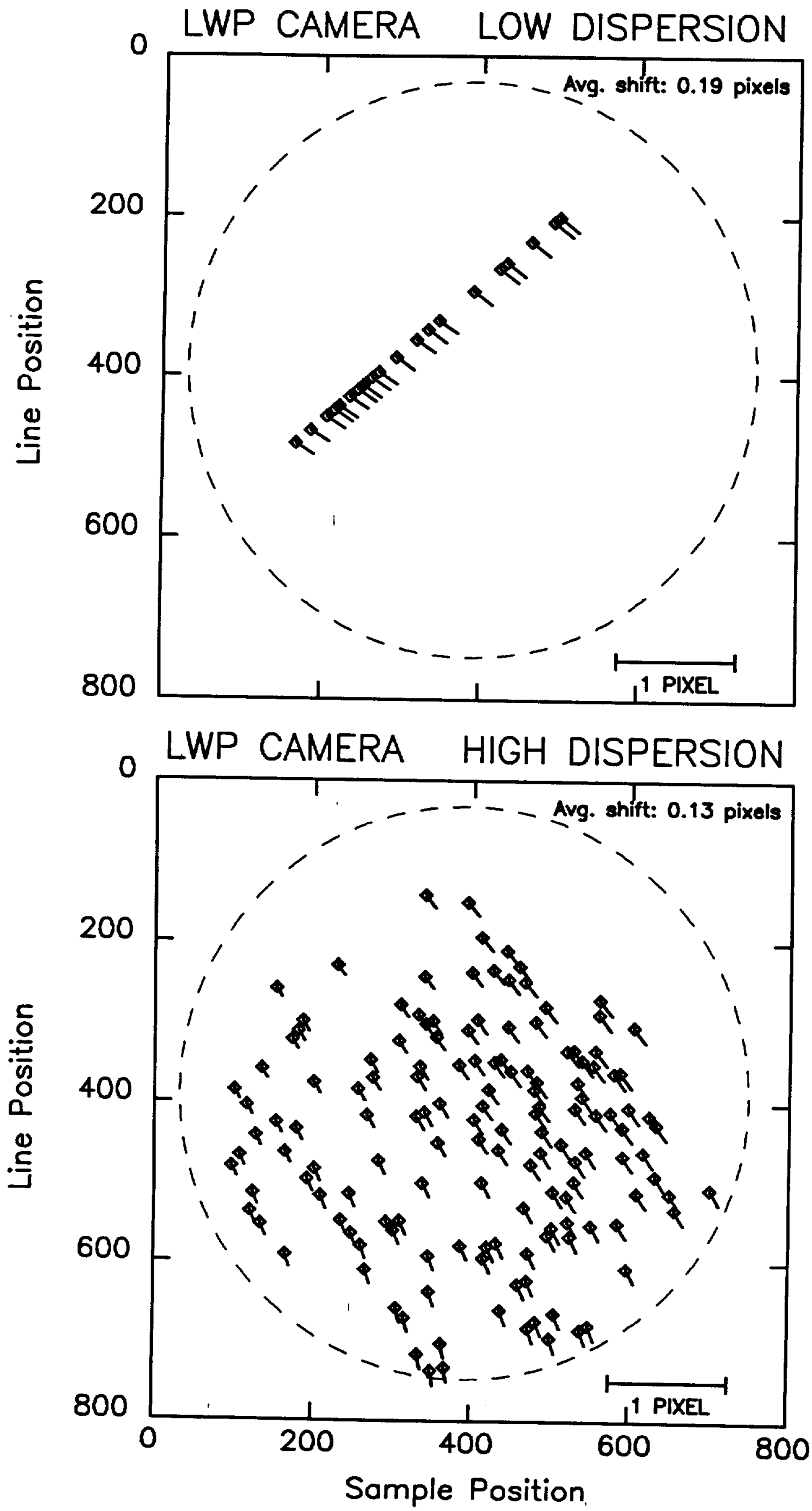
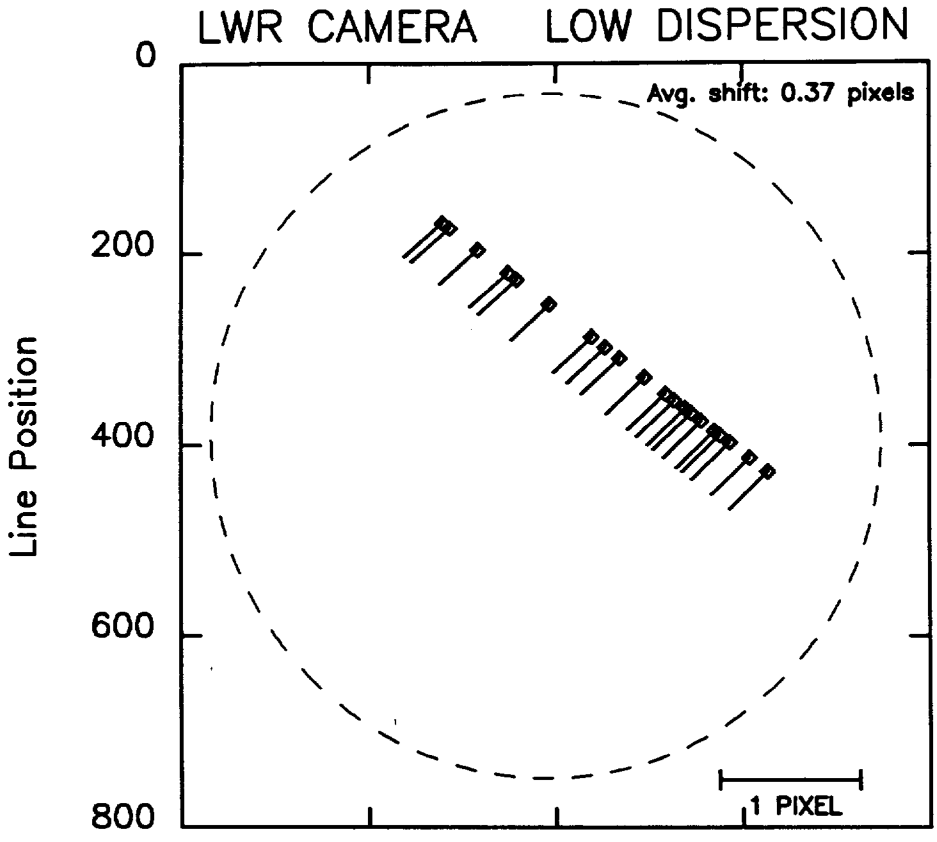
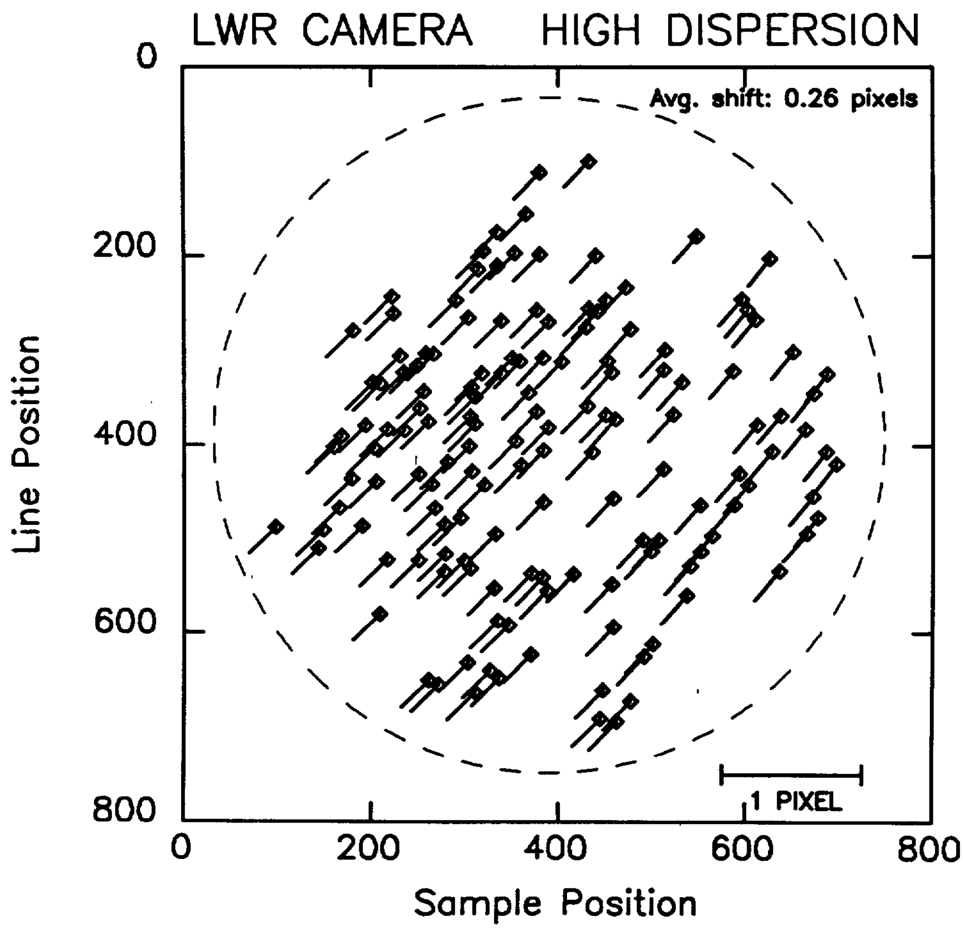

LWP CAMERA LOW DISPERSION
Avg. shift: 0.19 pixels
1 PIXEL
LWP CAMERA HIGH DISPERSION
Avg. shift: 0.13 pixels
1 PIXEL
Line Position
Line Position
Sample Position
0
200
400
600
800

Figure 14

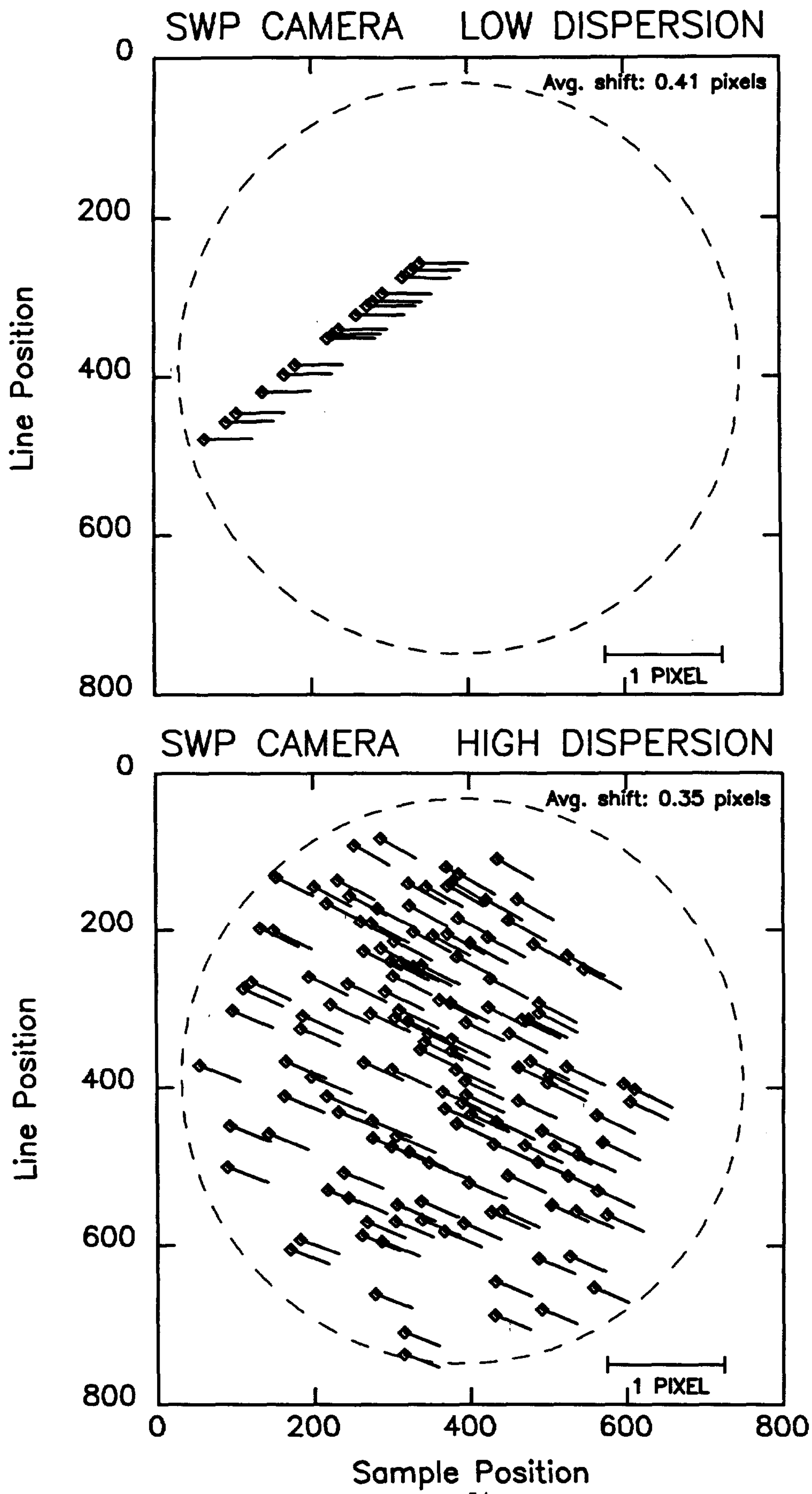


LWR CAMERA LOW DISPERSION
Avg. shift: 0.37 pixels
1 PIXEL
Line Position
0
200
400
600
800



LWR CAMERA HIGH DISPERSION
Avg. shift: 0.26 pixels
1 PIXEL
Line Position
0
200
400
600
800
Sample Position
0
200
400
600
800

Figure 15



SWP CAMERA LOW DISPERSION
Avg. shift: 0.41 pixels
1 PIXEL
0
200
400
600
800
Line Position
SWP CAMERA HIGH DISPERSION
Avg. shift: 0.35 pixels
1 PIXEL
0
200
400
600
800
Line Position
0
200
400
600
800
Sample Position