Effects of Gaps in Scatterometer Raw Data on σ^0-Triplets

Progress Meeting

1. June 1995

Agenda

1. Purpose of the Study
2. General Approach
3. Analysis of Effect on Spatial Filtering Process
4. Analysis of Effect on the Complete Ground Processing
5. Conclusions
6. Further Proceeding (Discussion)

1. Purpose of the Study

The Active Microwave Instrument (AMI) of the ERS satellites can be operated in three principle measurement modes:

- imave mode for high resolution imaging
- wave mode for ocean spectrum measurement
- wind mode for wind observation over the oceans

The current wind scatterometer ground processing implementation is designed for the AMI wind mode.

The wind and wave modes can be operated in an interleaved way, the wind/wave mode. Since launch of ERS-1, this mode has become the normal mode of operation for wind observation

The wind/wave mode introduces gaps into the otherwise continues scatterometer measurement data stream (2 Fore/mid/Aft (FMA)-sequences missing every 32 FMA sequences).

The purpose of this study is to

- analyse the effect of gaps in the source packet stream (wind/wave mode, instrument switch on/off) on the level 1b products (σ^0-triplets and associated information) (up to this PM)
- propose modifications to the processing to reduce these effects

2. General Approach

The following processing steps involve more than one source packet at a time and are therefore affected by missing source packets:

- ADC non-linearity correction (correction factor calculation)
- Internal calibration correction (correction factor calculation)
- Spatial integration
- kp - calculation

The quantitative effects of missing source packets on AMI wind mode σ^0-products were assessed in two steps:

a) analysis of the effect on the spatial filtering process (the most significantly affected process)
b) analysis of the effect on the complete ground processing.

For step b) the Ground Processing Mode of the Scatterometer System Simulator running on a DEC/VAX 400 has been used for processing.

3. Analysis of Effect on Spatial Filtering Process (1)

Approach for the analysis of the effect on the spatial filtering process:

- a single, complete row of 19 nodes across track considered for all three antennas
- σ^0 computed (using CMOD4 wind model) for
  - windspeeds of 4, 14 and 24m/s constant across spatial filter area
  - incidence angles pertinent to the individual echo samples
  - various angles between antenna and wind vector (look angles)
- four cases were considered
  - the undisturbed case (continuous source packet stream)
  - the case with wind/wave gaps (two missing source packets)
  - instrument switch-on case (´filling case´)
  - instrument switch-off case (´emptying case´)
- all possible positions (with respect to the spatial filter area) of the ´event´ are considered
- the effects on
  - the resultant σ^0 (expectation value)
  - the resultant Kp (speckle only)
  - the centre of gravity (GoG) of the spatial filter function in along and across track position
  - the CoG of the incidence angle and the ´look angle´

  are calculated for all three cases of missing source packets

Explanation of Missing Source Packet Effect

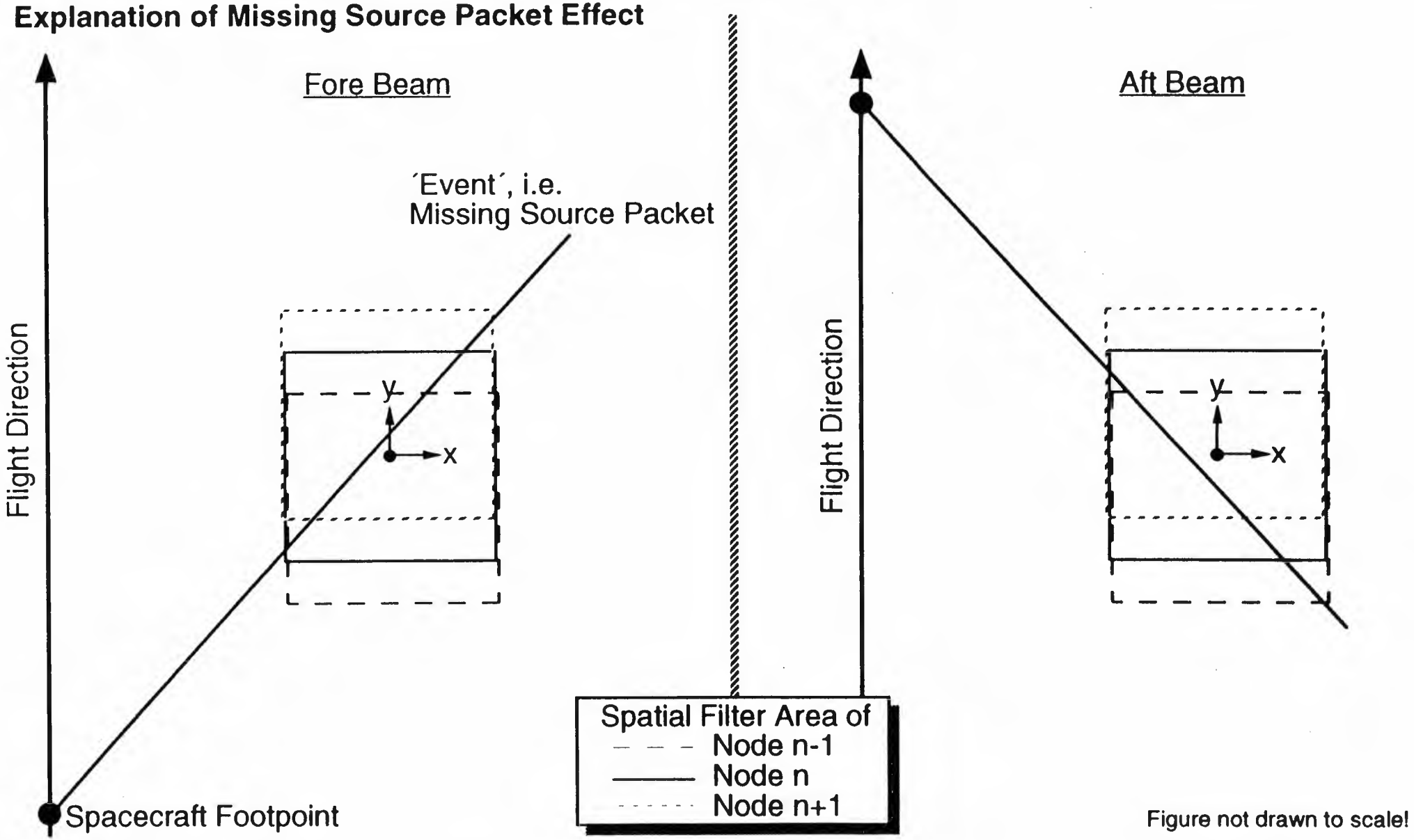

Figure not drawn to scale!

3. Analysis of Effect on Spatial Filtering Process (2)

Effect on resultant σ^0:

- the influence of the look angle on the effect is small
- in general the relative error of the fore or aft beam is significantly greater (one to two orders of magnitude) than the relative errors of the mid beam. This is caused by the fact that for the fore and aft beam source packets are missing in the corners of the spatial filter area
- the relative error decreases significantly from near range to far range (windspeed 4m/s, fore beam):
  - wind/wave mode: 4% for node 1, 1% for node 11, and 0.4% for node 19
  - instrument switch-on: 150% for node 1, 25% for node 11, and 11% for node 19
  - instrument switch-off: -60% for node 1, -17% for node 11, and -5% for node 19
- the maximum relative error decreases slightly with increasing wind speeds (node 1, fore beam):
  - wind/wave mode: 4% for 4m/s, 3% for 14m/s, and 2.5% for 24m/s
  - instrument switch-on: 150% for 4m/s, 100% for 14m/s, and 70% for 24m/s
  - instrument switch-off: -60% for 4m/s, -47% for 14m/s, and -38% for 24m/s

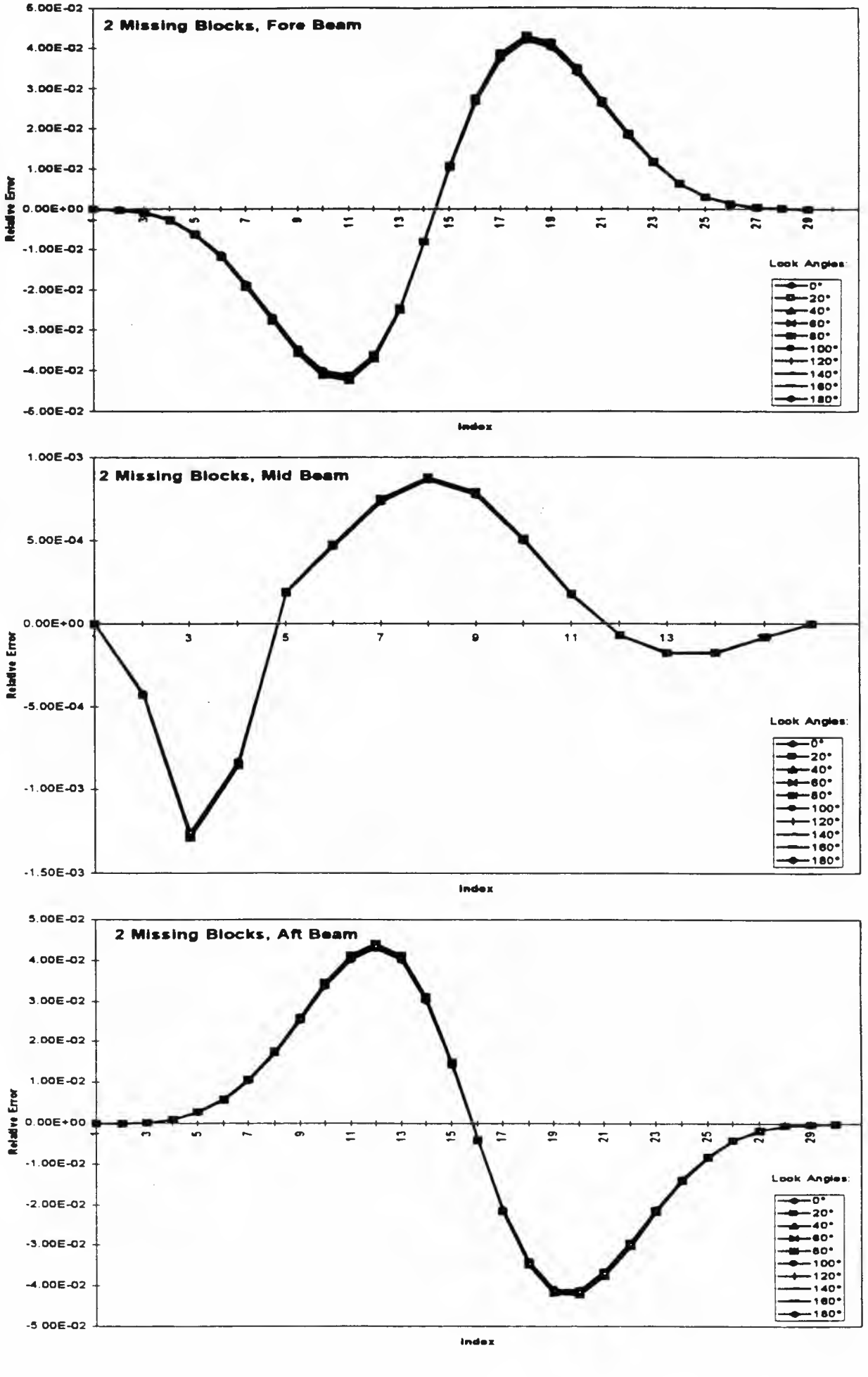

Figure D1: Relative Error of Sigma-0 Values, Node 1, Windspeed 4 m/s, Two Missing Blocks

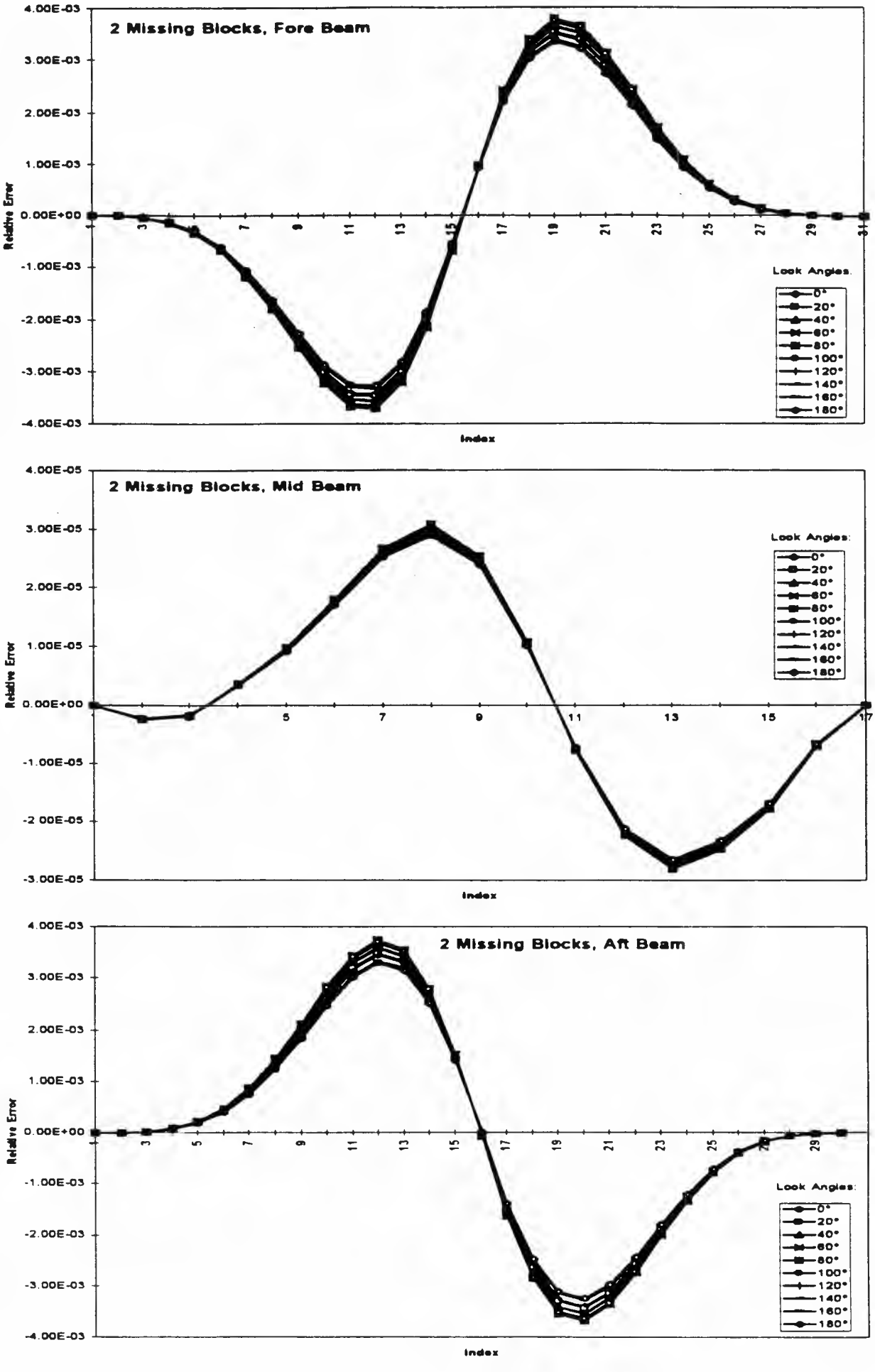

Figure D3: Relative Error of Sigma-0 Values, Node 19, Windspeed 4 m/s, Two Missing Blocks

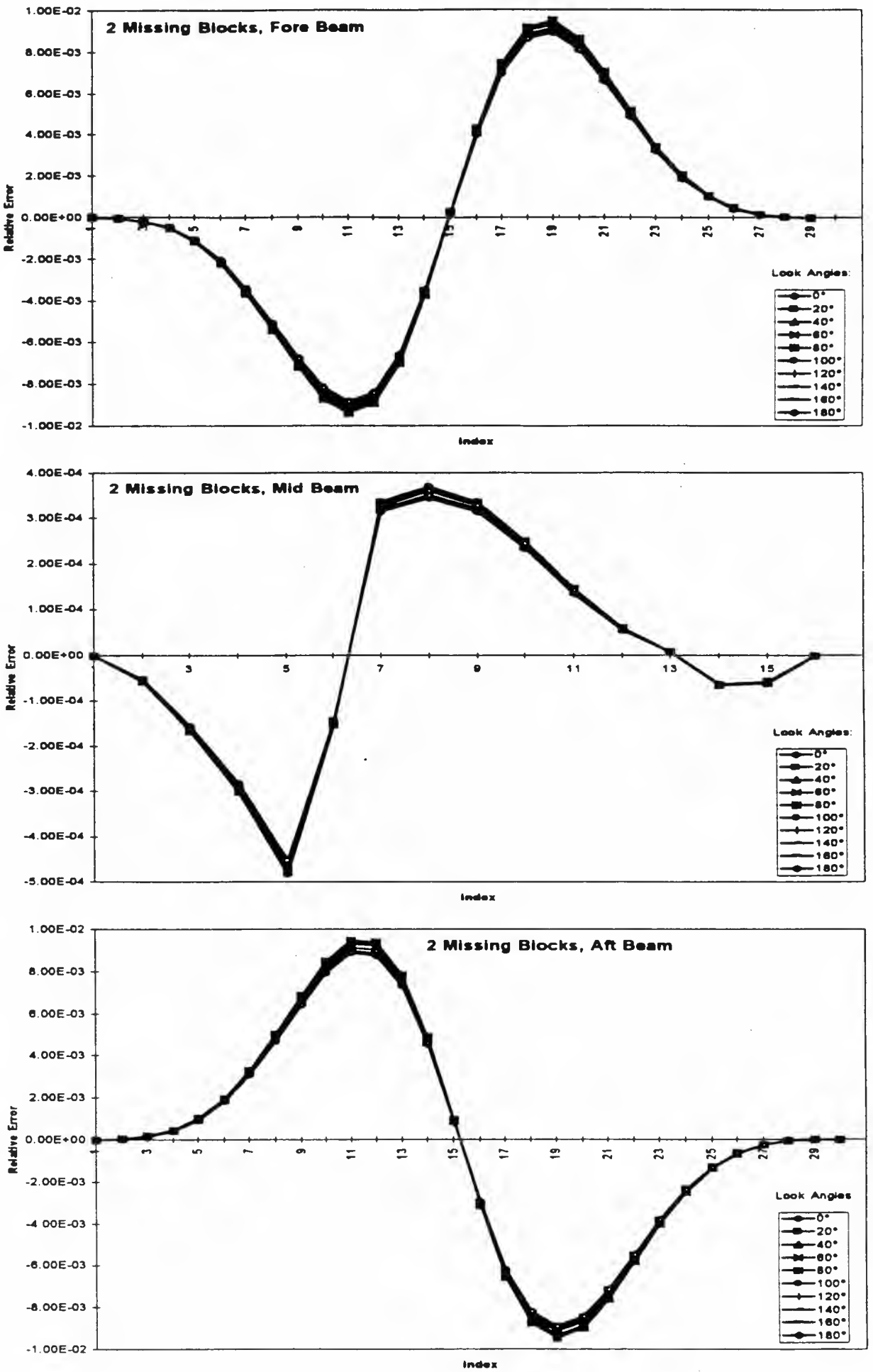

Figure D2: Relative Error of Sigma-0 Values, Node 11, Windspeed 4 m/s, Two Missing Blocks

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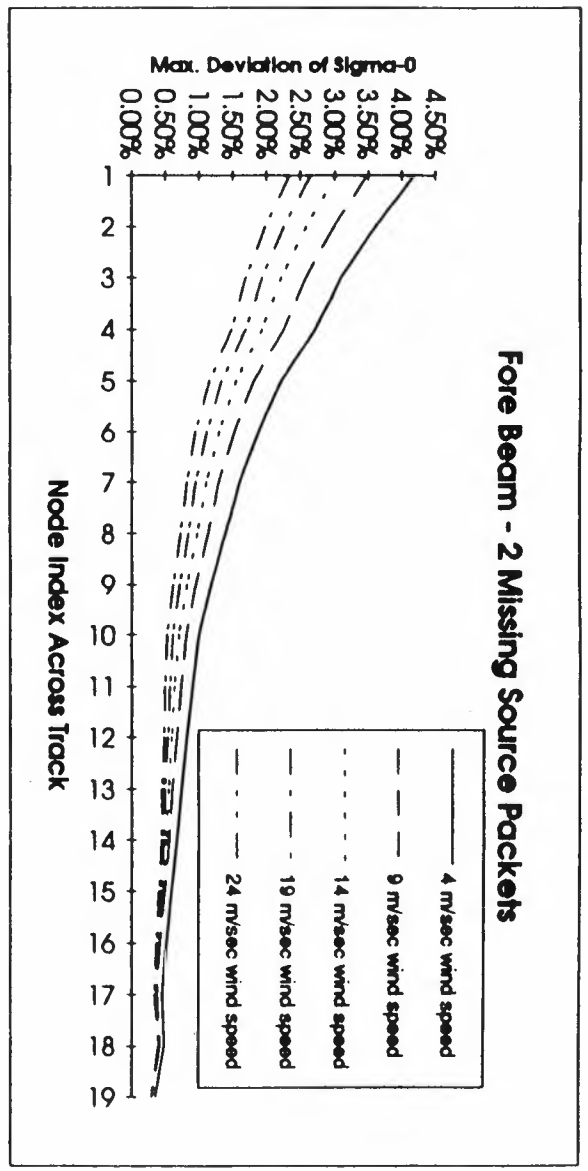
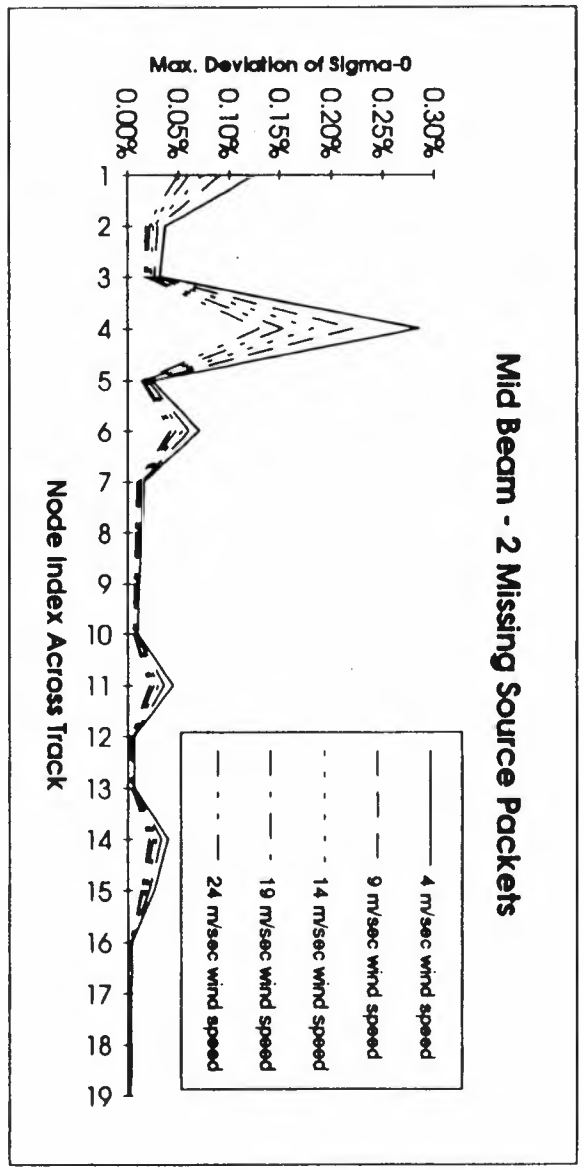
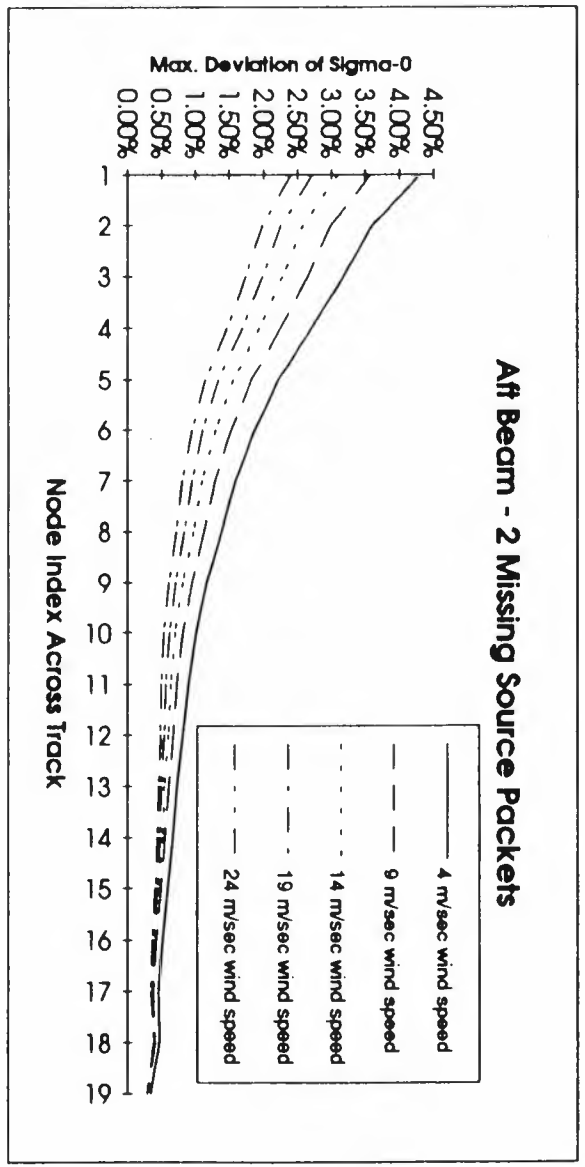
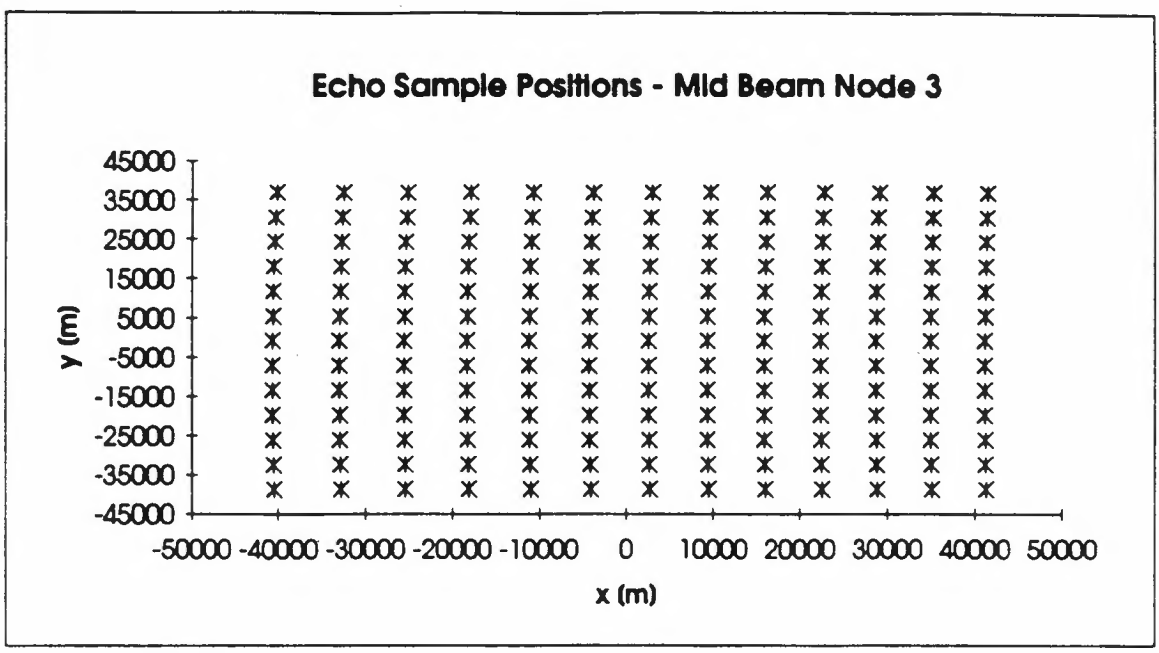
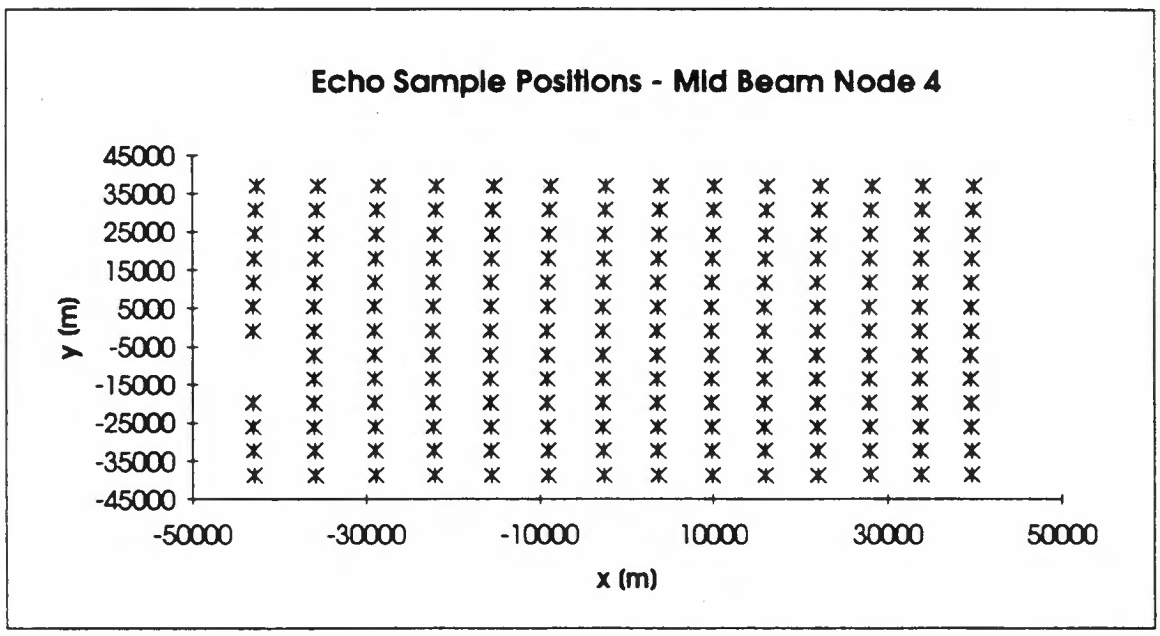
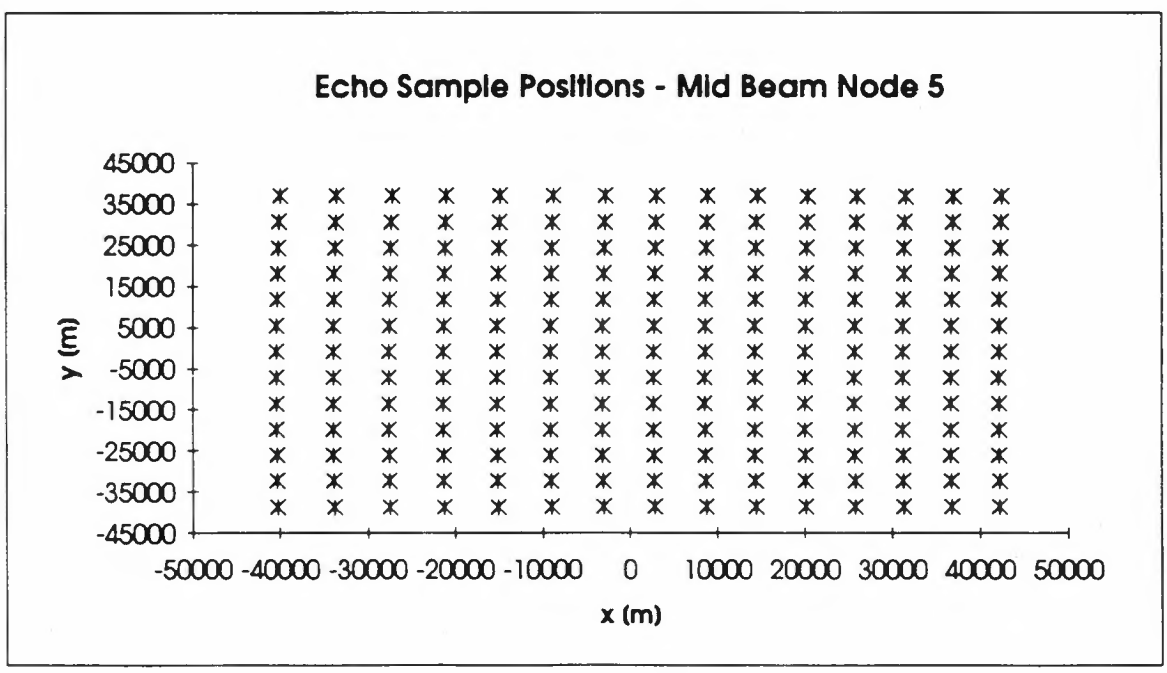


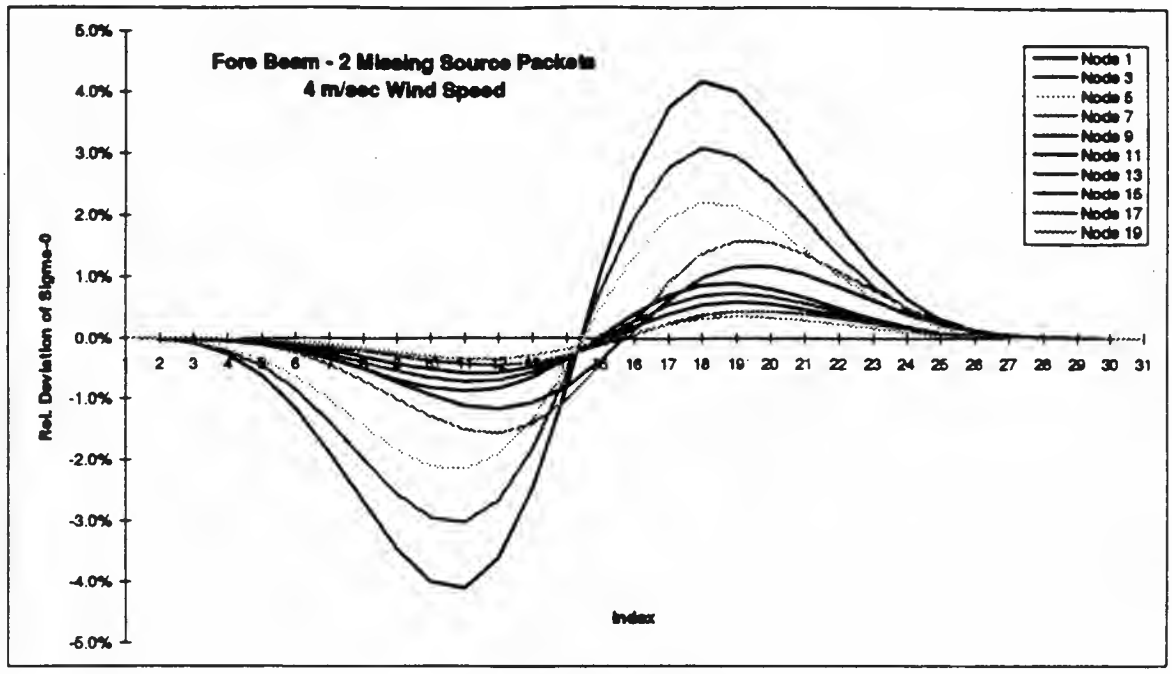


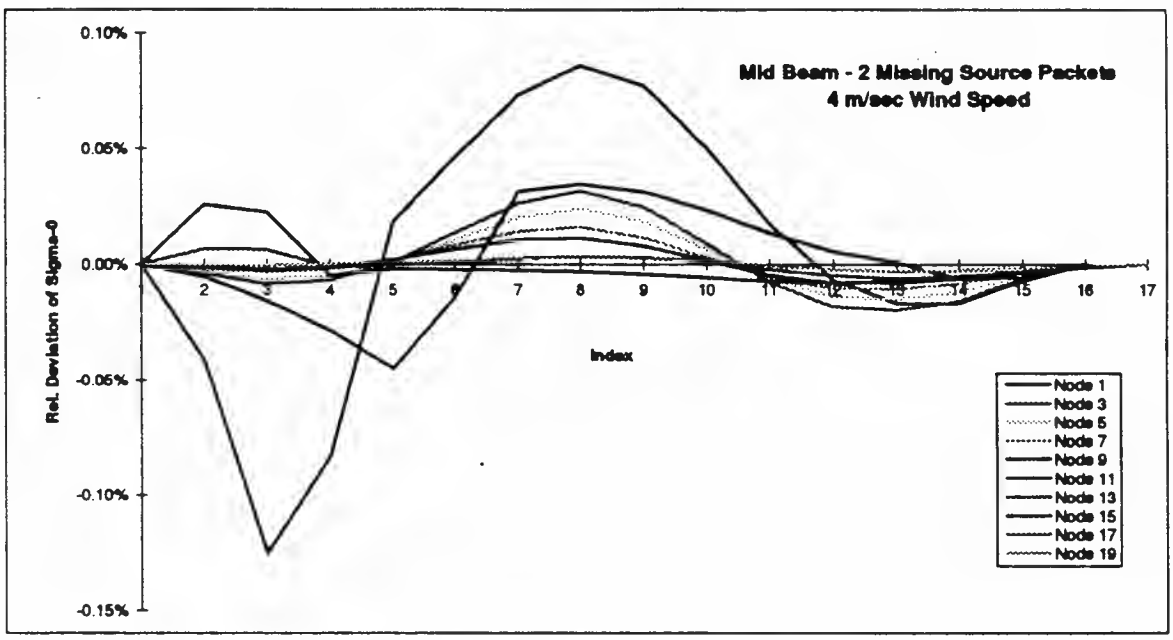


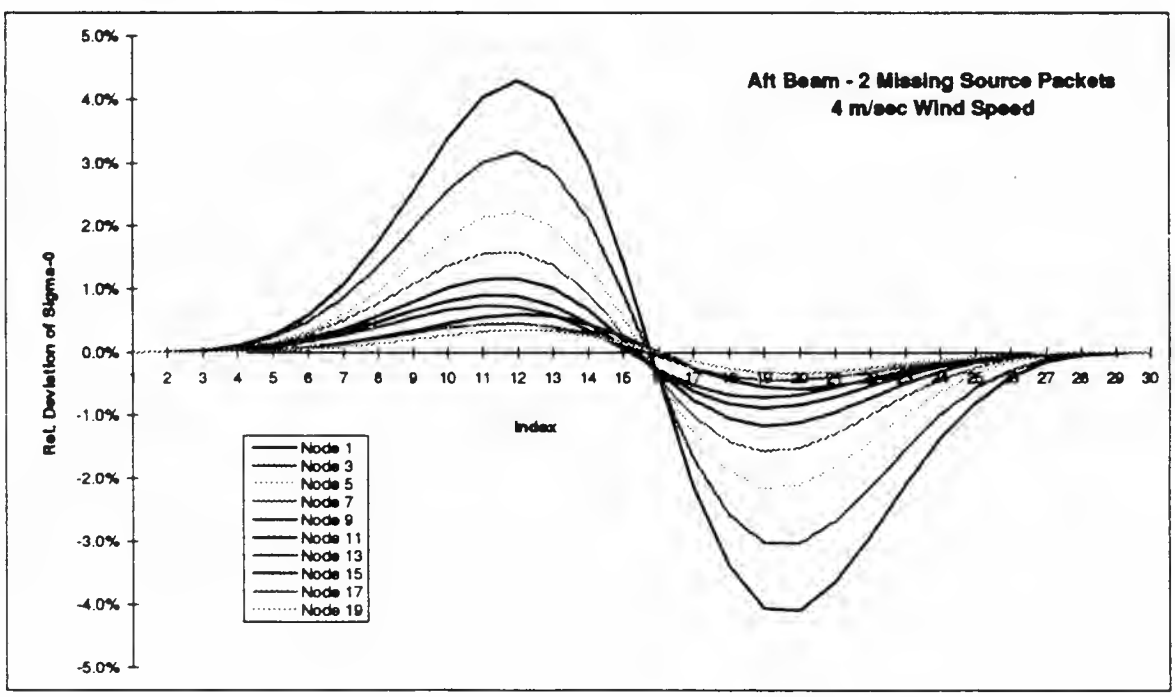

Echo Sample Positions - Mid Beam Node 3
45000
35000
25000
15000
5000
-5000
-15000
-25000
-35000
-45000
y (m)
-50000 -40000 -30000 -20000 -10000 0 10000 20000 30000 40000 50000
x (m)


Echo Sample Positions - Mid Beam Node 4
45000
35000
25000
15000
5000
-5000
-15000
-25000
-35000
-45000
y (m)
-50000 -30000 -10000 10000 30000 50000
x (m)


Echo Sample Positions - Mid Beam Node 5
45000
35000
25000
15000
5000
-5000
-15000
-25000
-35000
-45000
y (m)
-50000 -40000 -30000 -20000 -10000 0 10000 20000 30000 40000 50000
x (m)


Fore Beam - 2 Missing Source Packets
4 m/sec Wind Speed
Rel. Deviation of Sigma-0
Index
Node 1
Node 3
Node 5
Node 7
Node 9
Node 11
Node 13
Node 15
Node 17
Node 19


Mid Beam - 2 Missing Source Packets
4 m/sec Wind Speed
Rel. Deviation of Sigma-0
Index
Node 1
Node 3
Node 5
Node 7
Node 9
Node 11
Node 13
Node 15
Node 17
Node 19


Aft Beam - 2 Missing Source Packets
4 m/sec Wind Speed
Rel. Deviation of Sigma-0
Index
Node 1
Node 3
Node 5
Node 7
Node 9
Node 11
Node 13
Node 15
Node 17
Node 19

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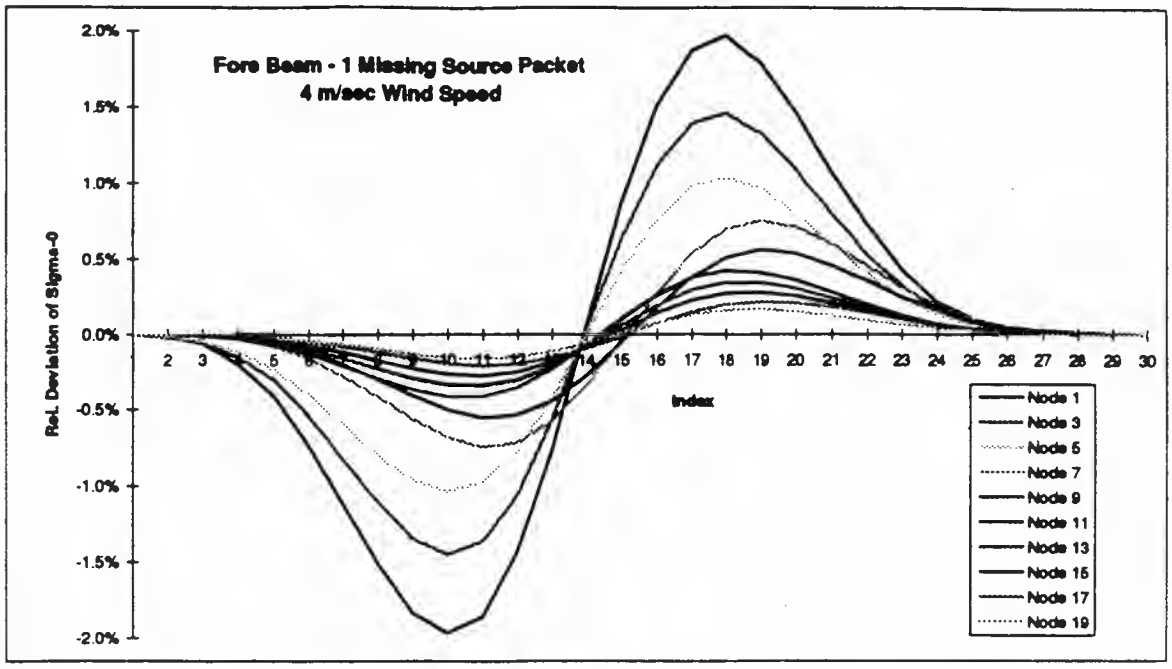

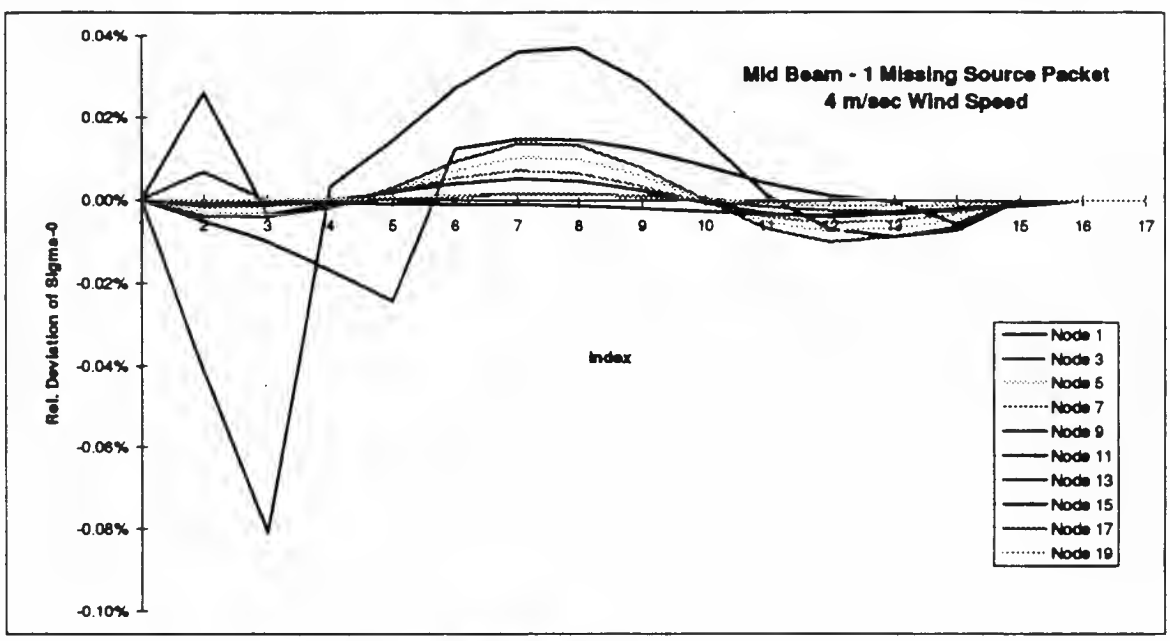

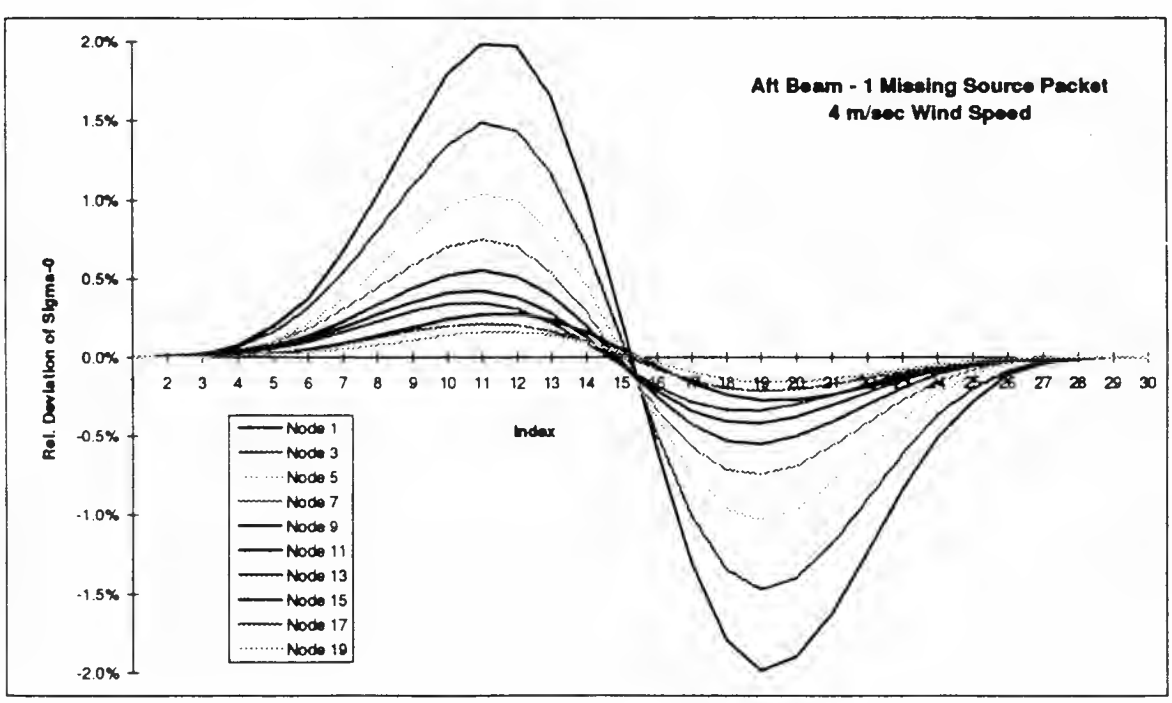

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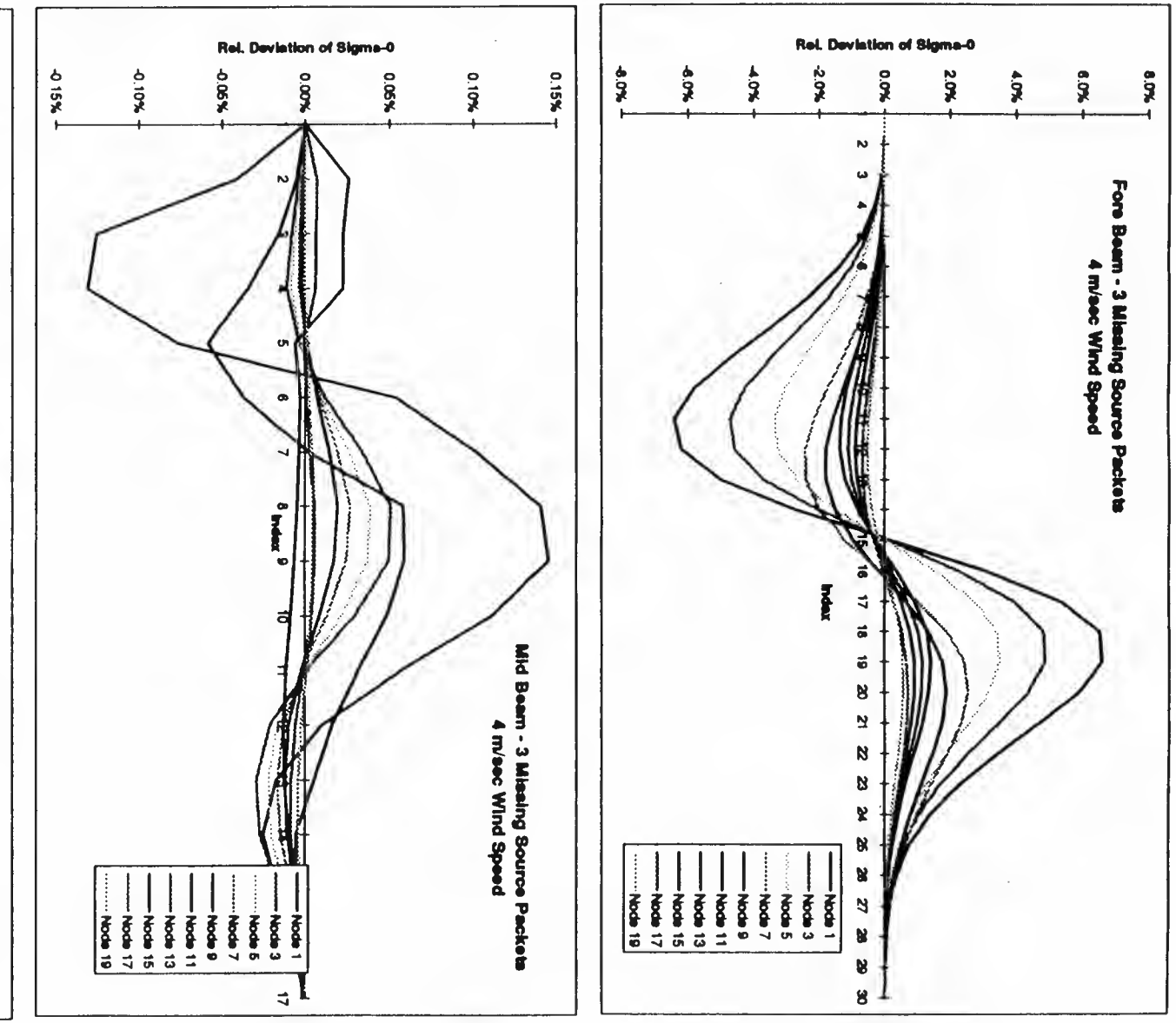
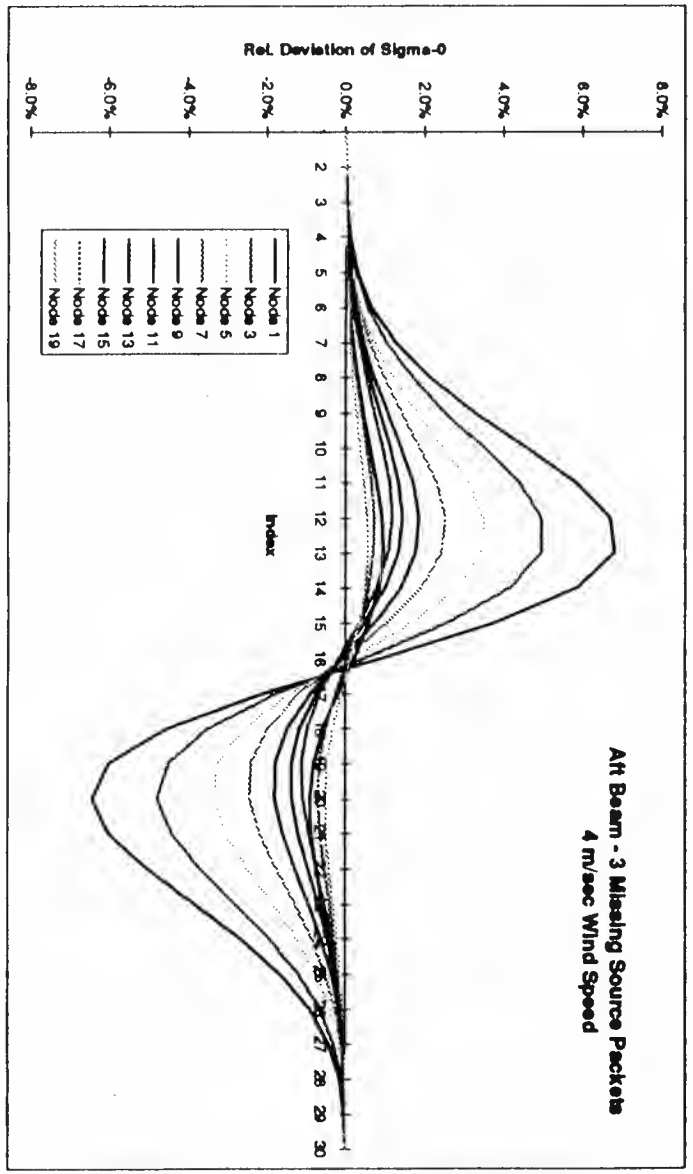




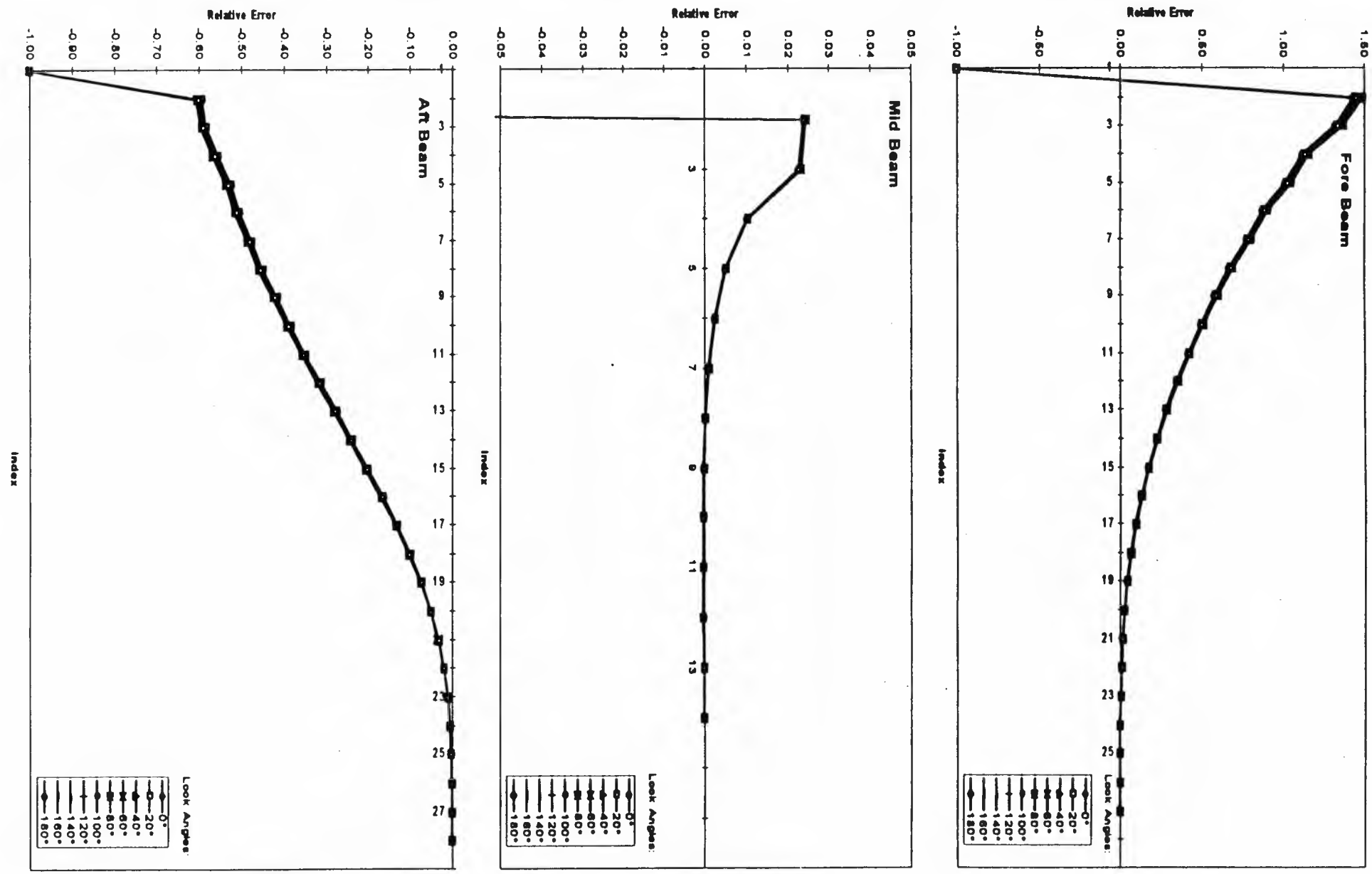
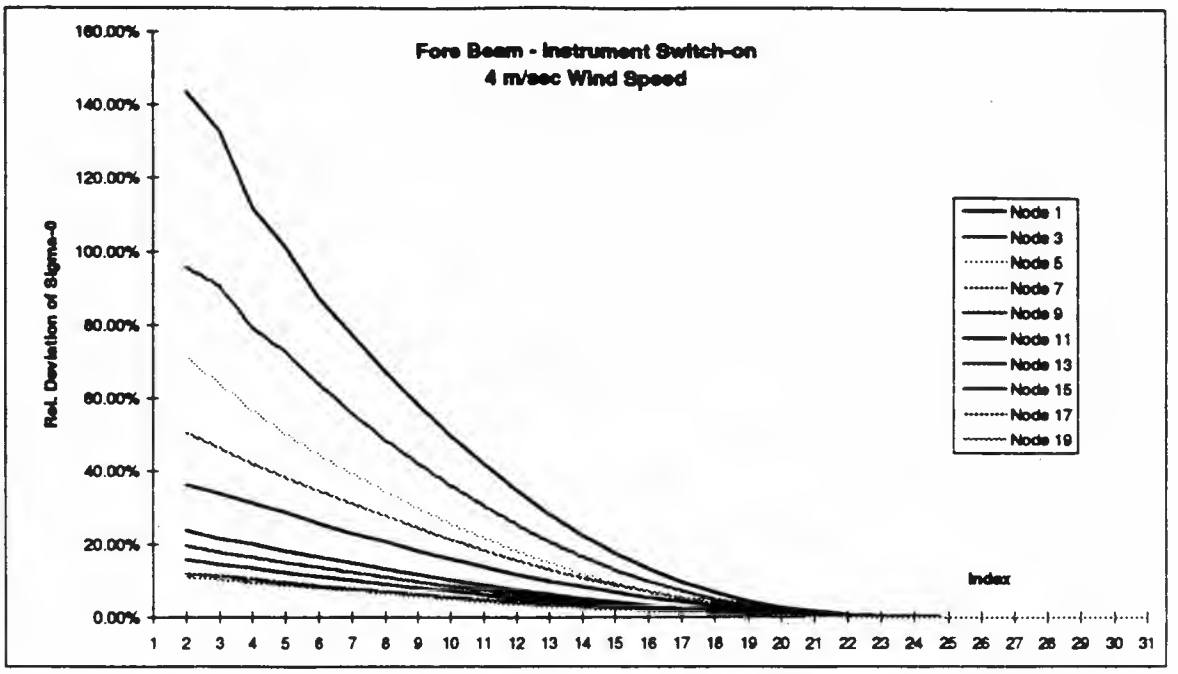
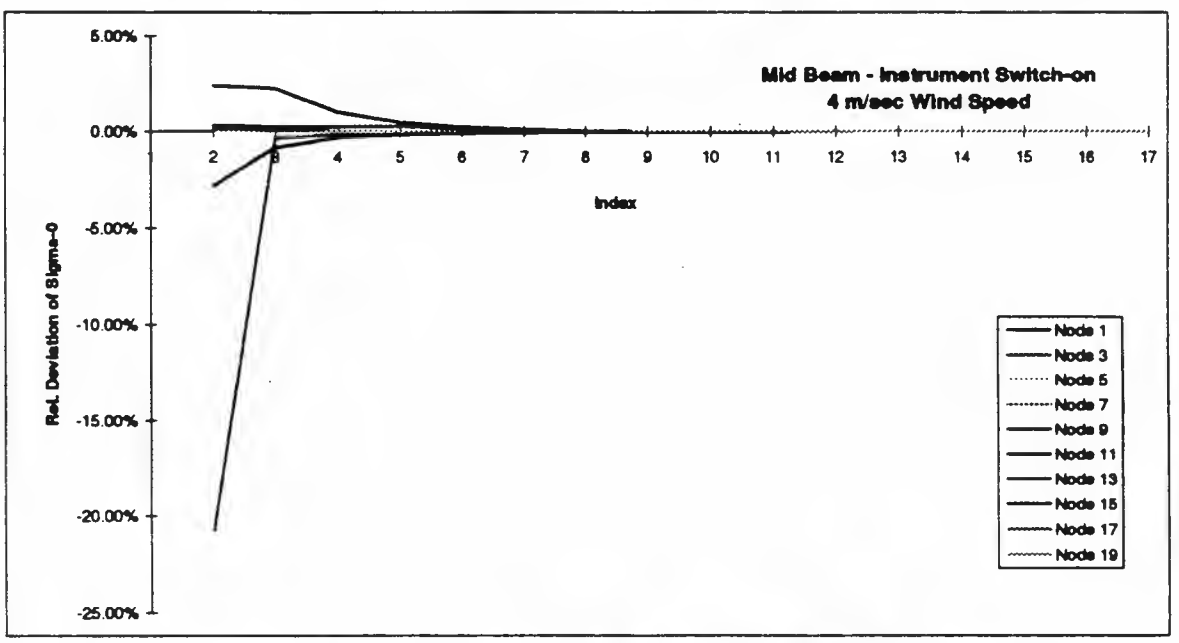
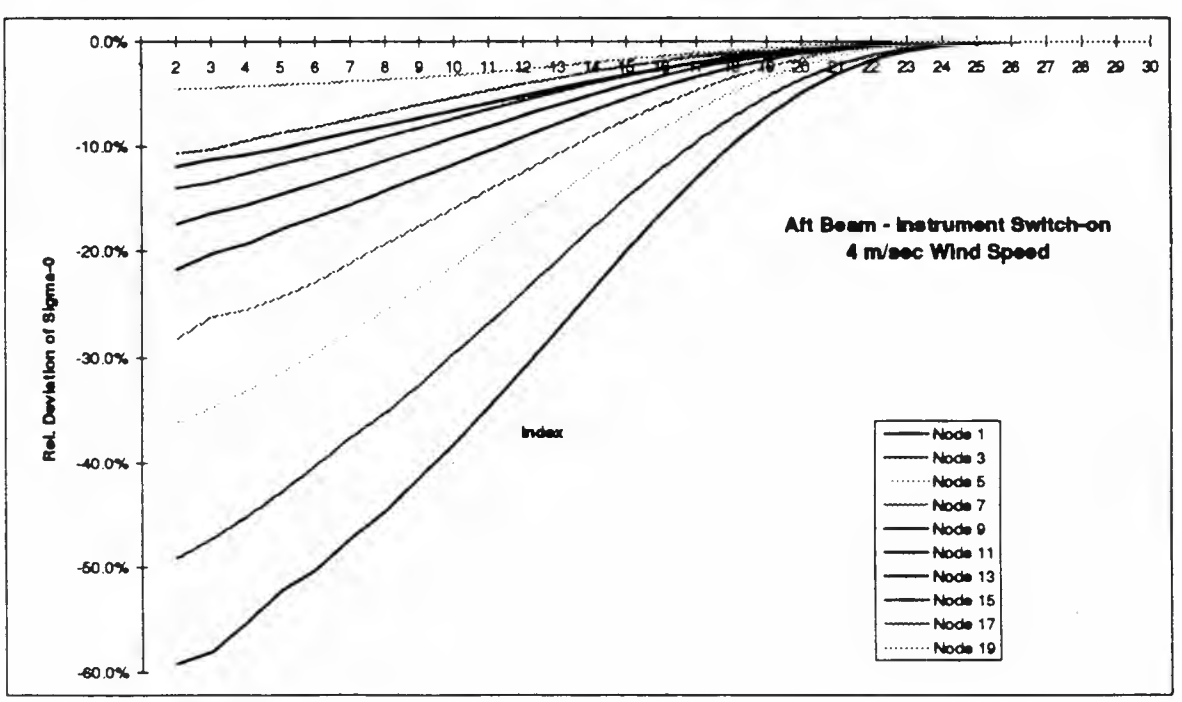


Figure D10: Relative Error of Sigma-0 Values, Node 1, Windspeed 4 m/s, Filling Case


Fore Beam - Instrument Switch-on
4 m/sec Wind Speed
Rel. Deviation of Sigma-0
Index
Node 1
Node 3
Node 5
Node 7
Node 9
Node 11
Node 13
Node 15
Node 17
Node 19


Mid Beam - Instrument Switch-on
4 m/sec Wind Speed
Rel. Deviation of Sigma-0
Index
Node 1
Node 3
Node 5
Node 7
Node 9
Node 11
Node 13
Node 15
Node 17
Node 19


Aft Beam - Instrument Switch-on
4 m/sec Wind Speed
Rel. Deviation of Sigma-0
Index
Node 1
Node 3
Node 5
Node 7
Node 9
Node 11
Node 13
Node 15
Node 17
Node 19

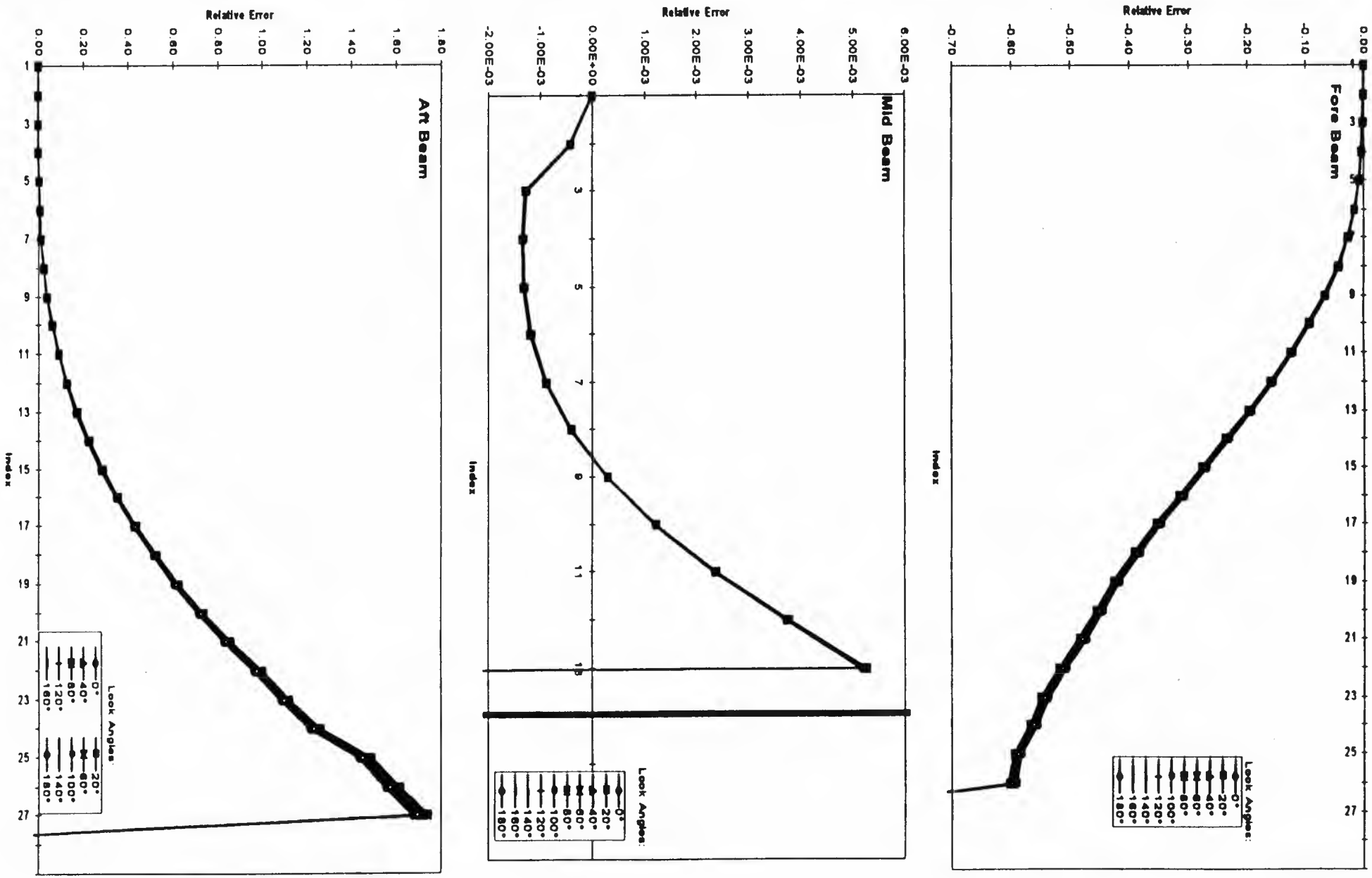
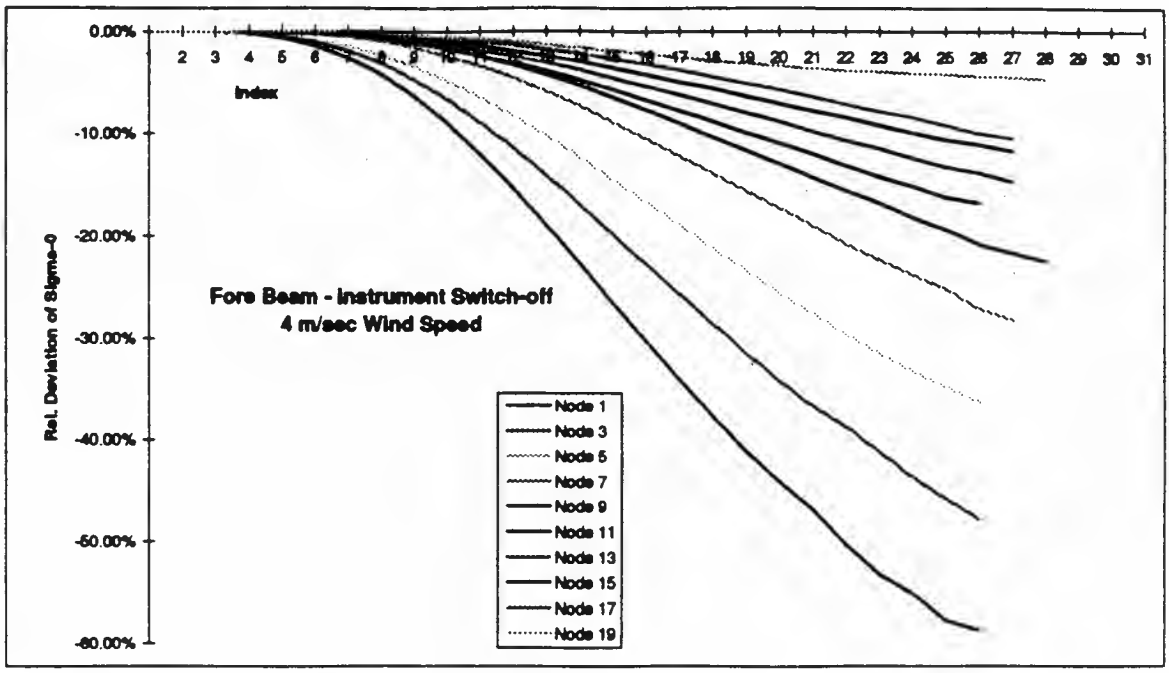
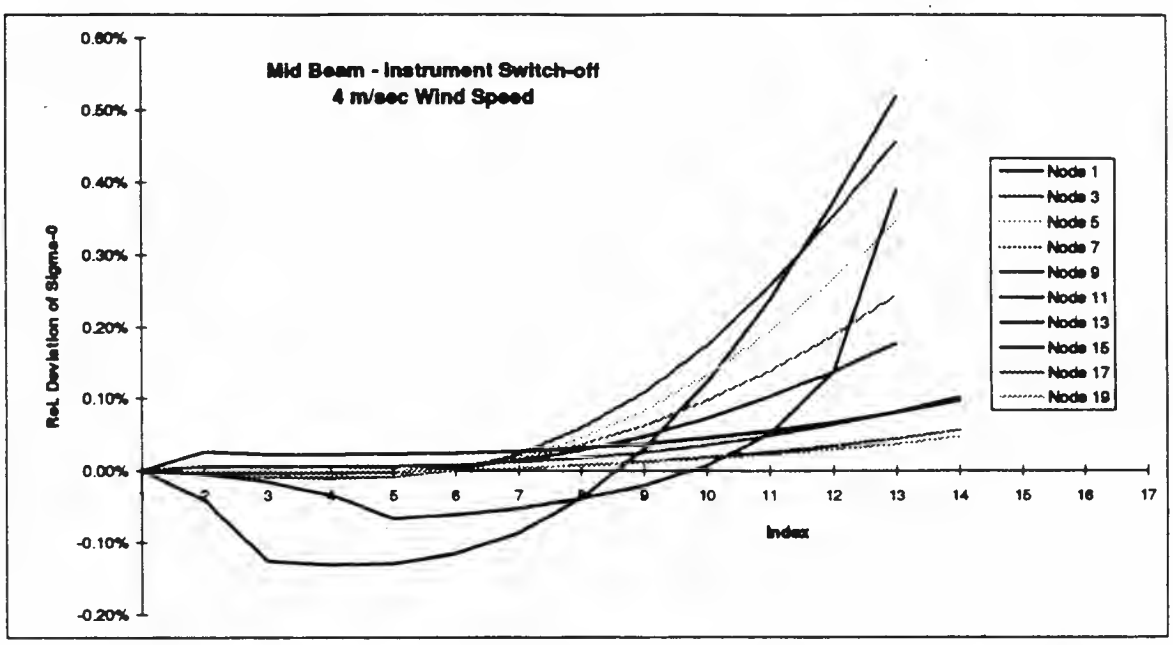
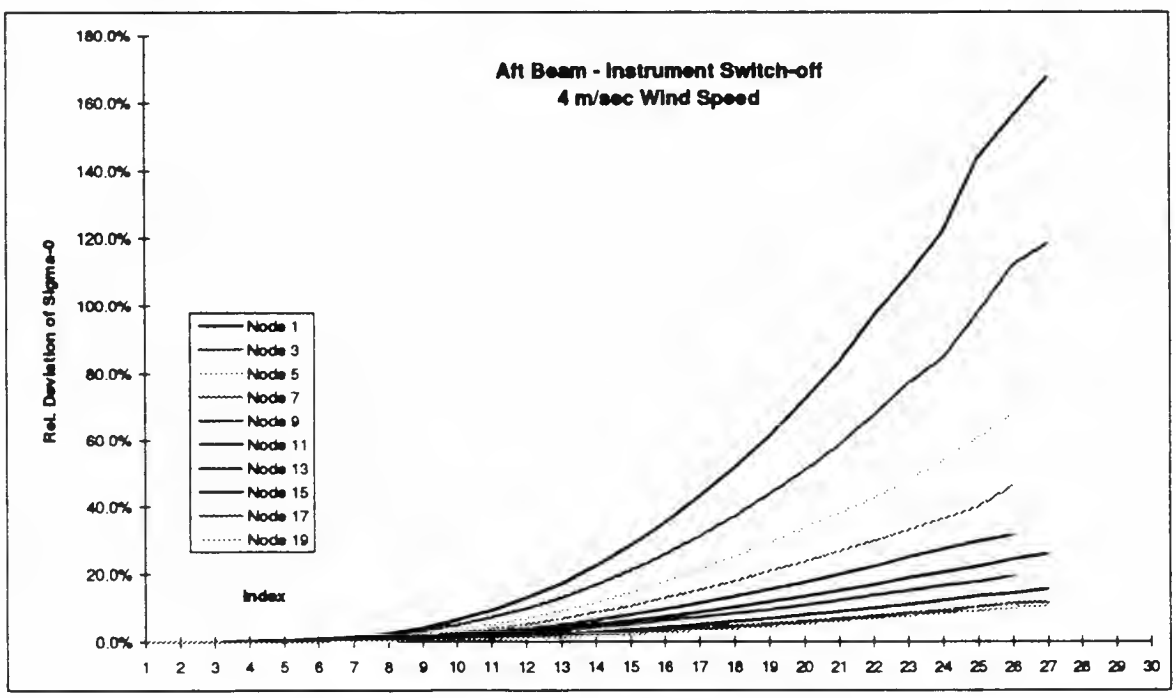


Figure D19: Relative Error of Sigma-0 Values, Node 1, Windspeed 4 m/s, Emptying Case


Fore Beam - Instrument Switch-off
4 m/sec Wind Speed
Rel. Deviation of Sigma-0
Index
0.00%
-10.00%
-20.00%
-30.00%
-40.00%
-50.00%
-60.00%
Node 1
Node 3
Node 5
Node 7
Node 9
Node 11
Node 13
Node 15
Node 17
Node 19


Mid Beam - Instrument Switch-off
4 m/sec Wind Speed
Rel. Deviation of Sigma-0
Index
0.60%
0.50%
0.40%
0.30%
0.20%
0.10%
0.00%
-0.10%
-0.20%
Node 1
Node 3
Node 5
Node 7
Node 9
Node 11
Node 13
Node 15
Node 17
Node 19


Aft Beam - Instrument Switch-off
4 m/sec Wind Speed
Rel. Deviation of Sigma-0
Index
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
Node 1
Node 3
Node 5
Node 7
Node 9
Node 11
Node 13
Node 15
Node 17
Node 19

3. Analysis of Effect on Spatial Filtering Process (3)

Further assumptions made for analysis of impact on kp-values:

- only speckle is considered
- echoes from different pulses are uncorrelated
- echo samples from the same pulse are correlated if their sampling distance is smaller than the pulse length. The correlation factor was calculated as the correlation factor of two rectangular pulses of equal length. The decorrelating effects of residual Doppler and quantisation noise were neglected.

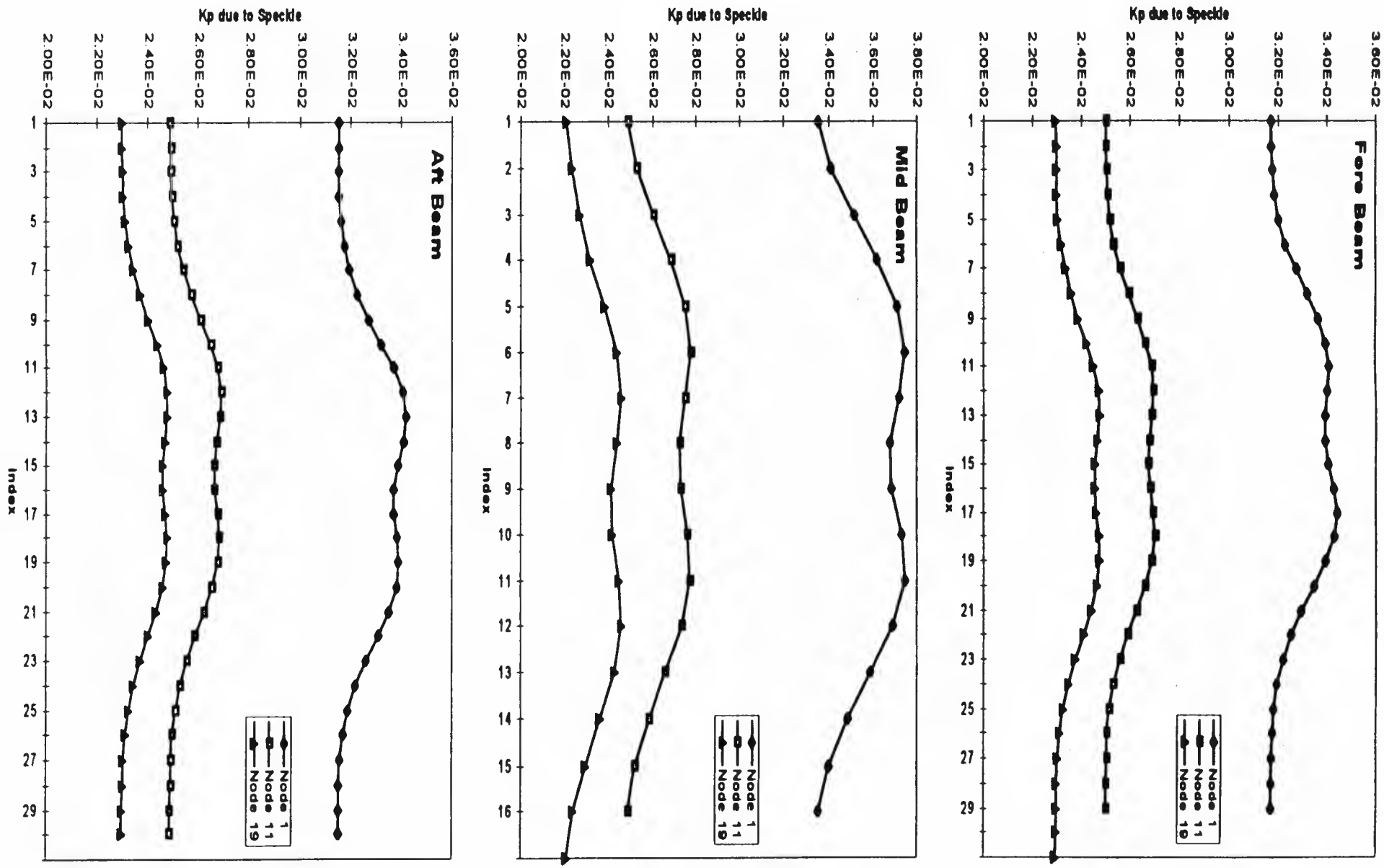


Figure E1: Kp Due to Speckle; Nodes 1, 11 and 19; Two Missing Blocks

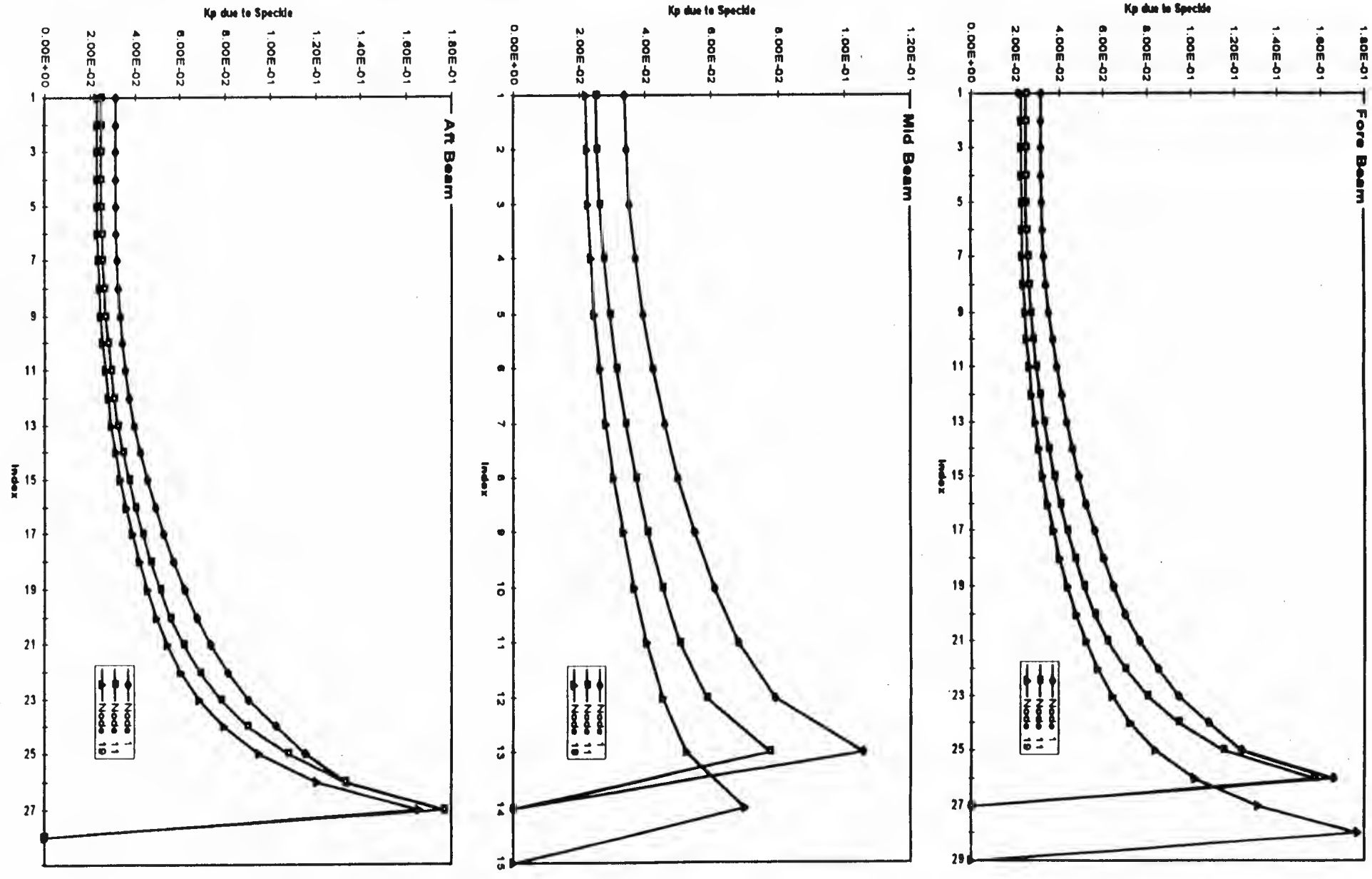


Figure E3: Kp Due to Speckle; Nodes 1, 11 and 19; Emptying Case

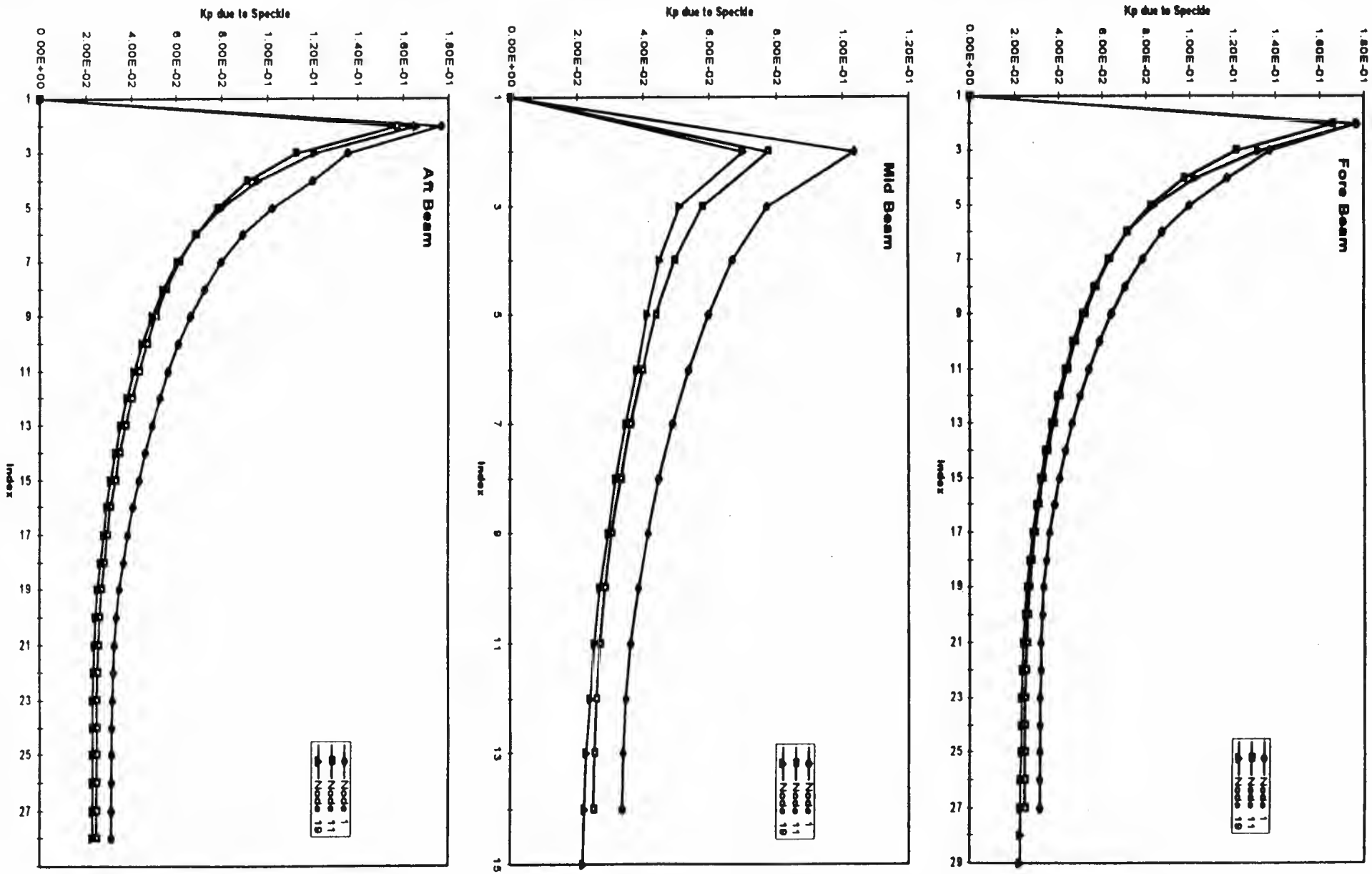


Figure E2: Kp Due to Speckle; Nodes 1, 11 and 19; Filling Case

3. Analysis of Effect on Spatial Filtering Process (4)

Effect on the Spatial Filter Weights:

General Note: Even for the undisturbed case the CoG of the spatial filter weights does not coincide with the node position.
It is shifted to the far range by approximately 250 to 750m (fore/aft beam) and 250 to 850m (mid beam).

The following table summarises the maximum deltas of the CoG.

Δ CoG [m]	Fore / Aft Beam		Mid Beam	
	x-Direction	y-Direction	x-Direction	y-Direction
Two Missing Blocks Case	± 1750 m	± 1750 m	± 45 m	± 3800 m
Filling Case	± 40000 m			
Emptying Case				

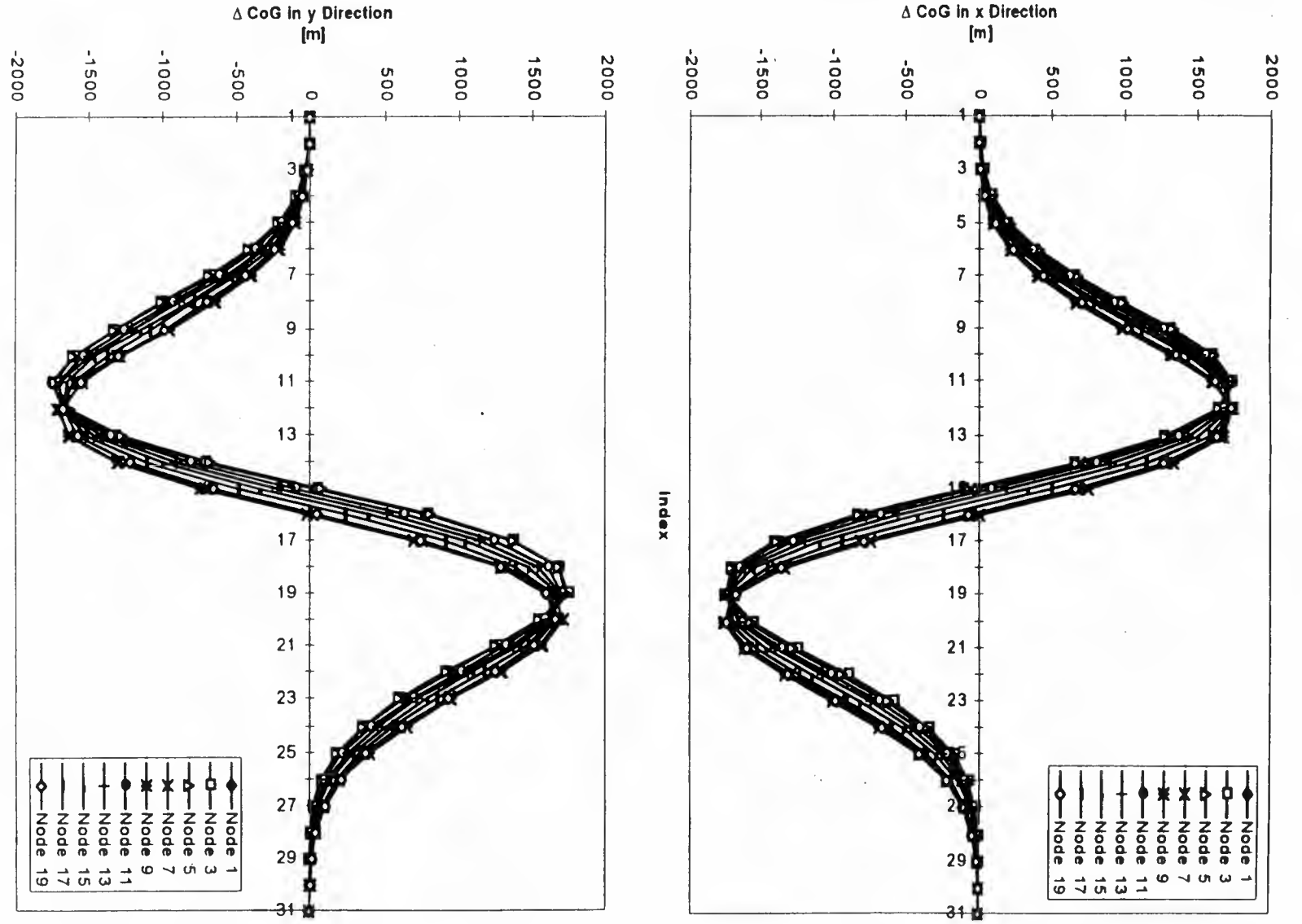


Figure A.1: Spatial Filter Weights, Δ CoG to Undisturbed Case in x- and y-Direction, Fore Beam, Two Missing Blocks

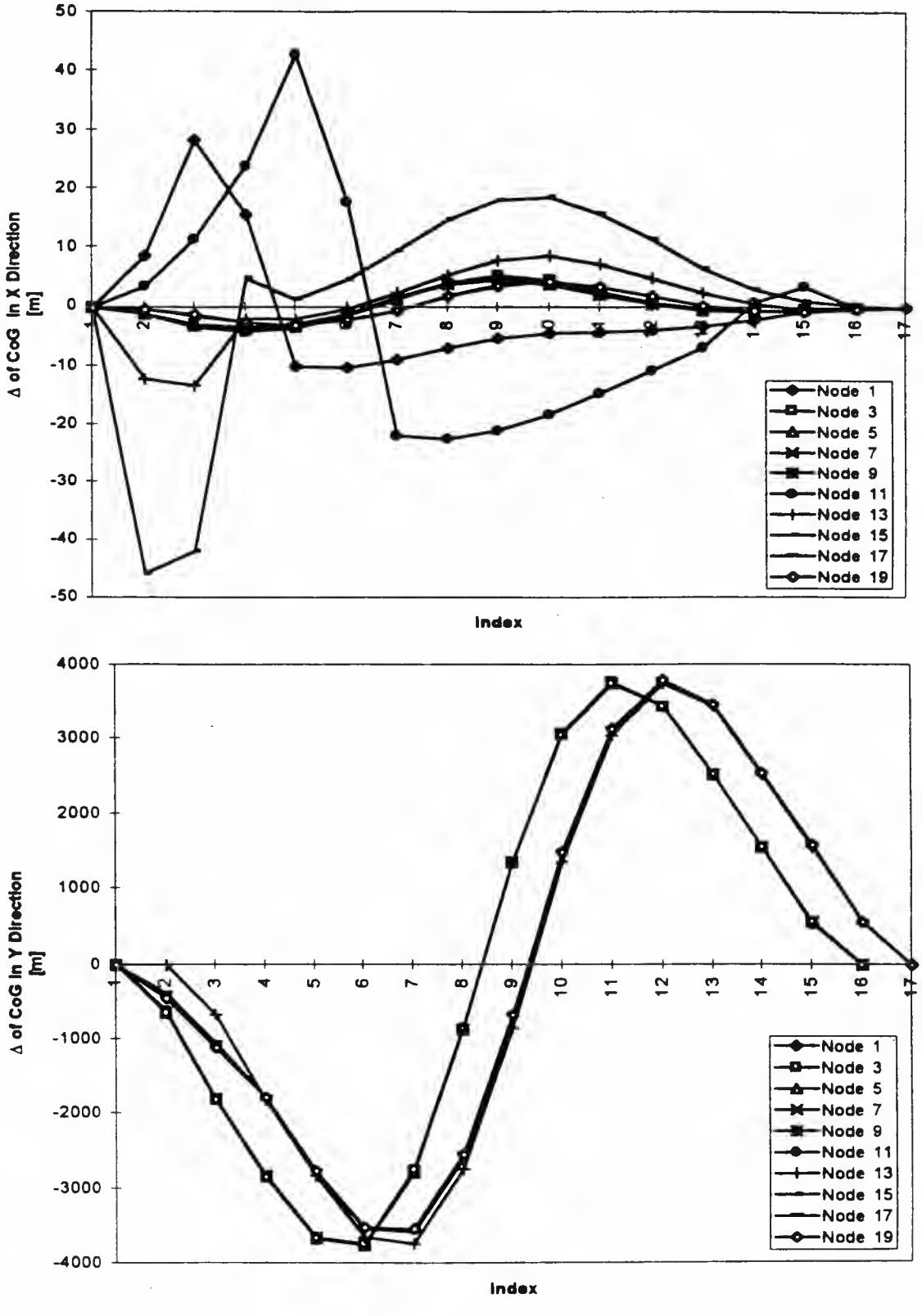


Figure A.2: Spatial Filter Weights, Δ CoG to Undisturbed Case in x- and y-Direction, Mid Beam, Two Missing Blocks

Figure A.3: Spatial Filter Weights, Δ CoG to Undisturbed Case in x- and y-Direction, Aft Beam, Two Missing Blocks

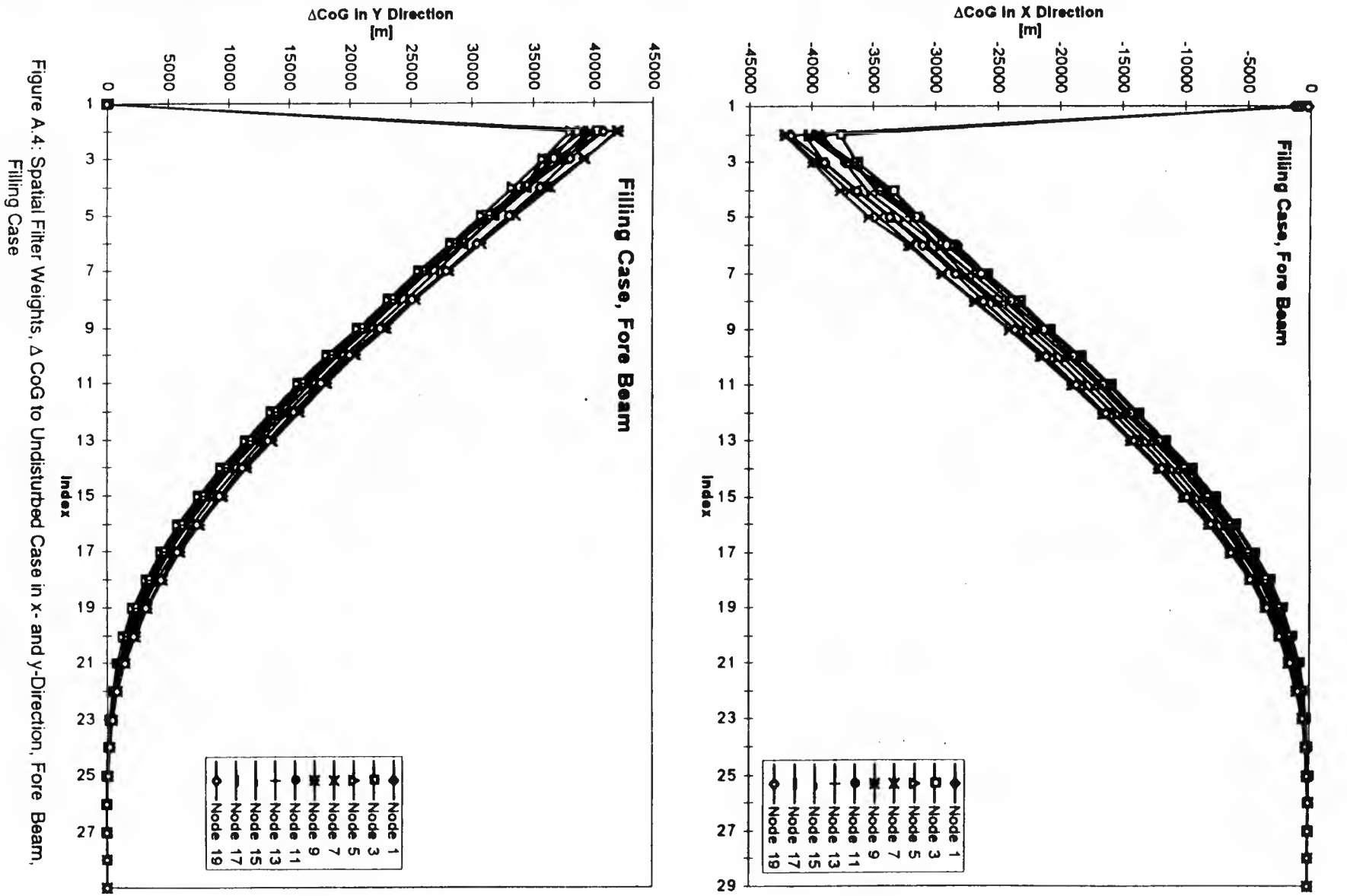


Figure A.4: Spatial Filter Weights, Δ CoG to Undisturbed Case in x- and y-Direction, Fore Beam, Filling Case

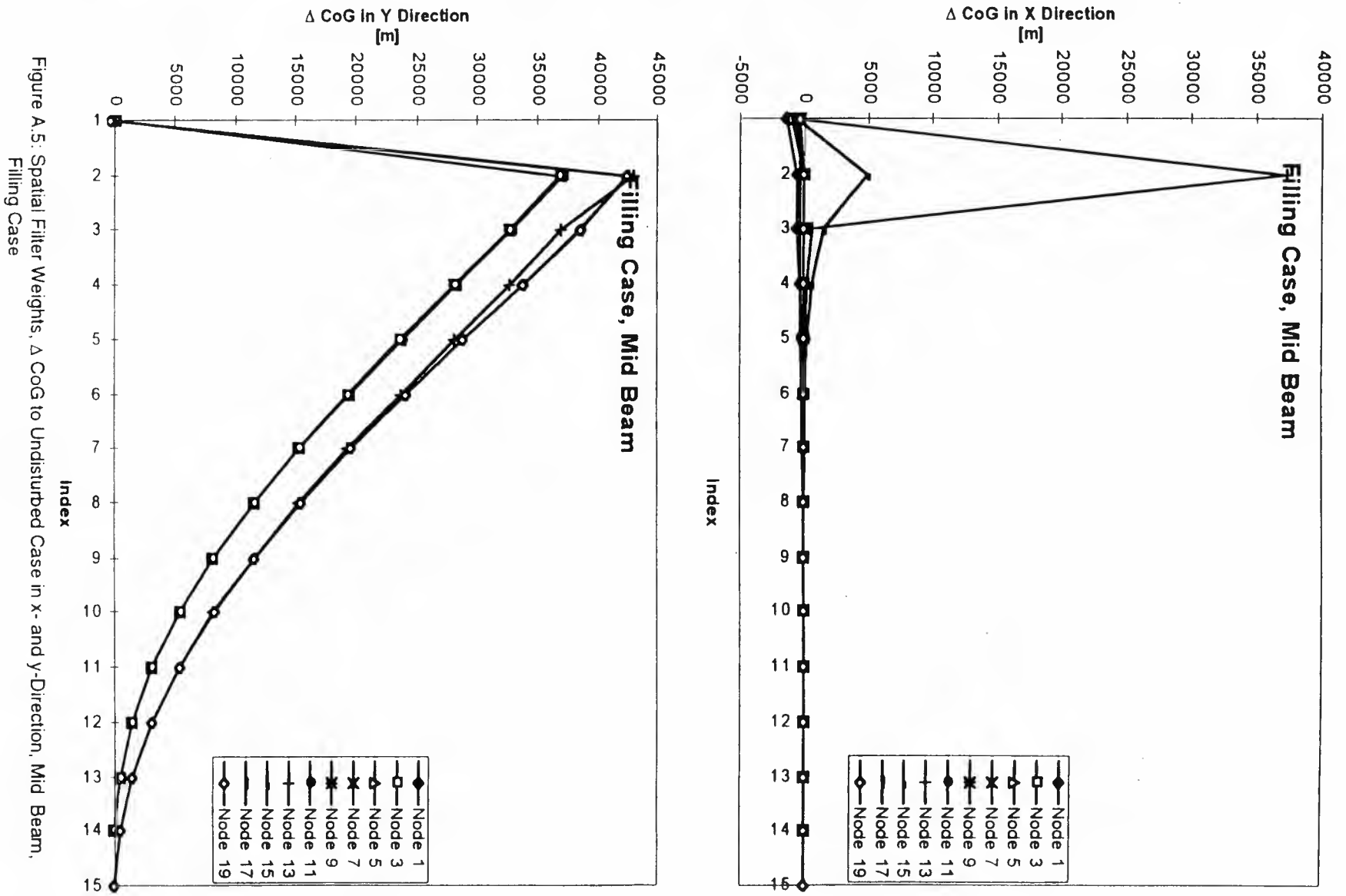
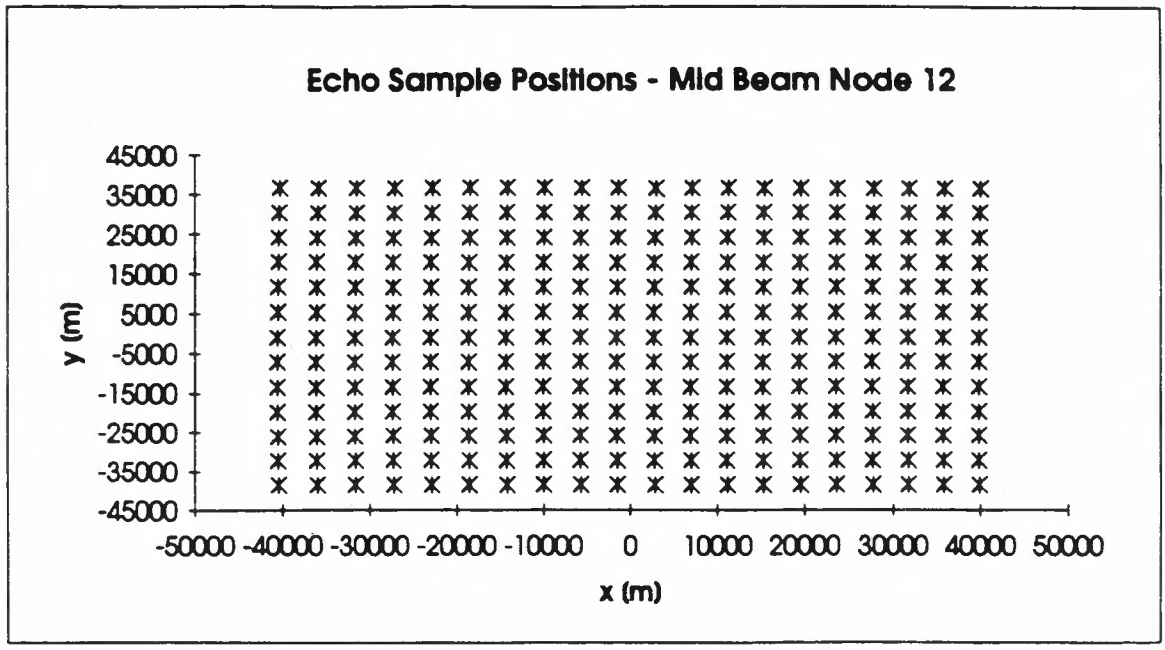
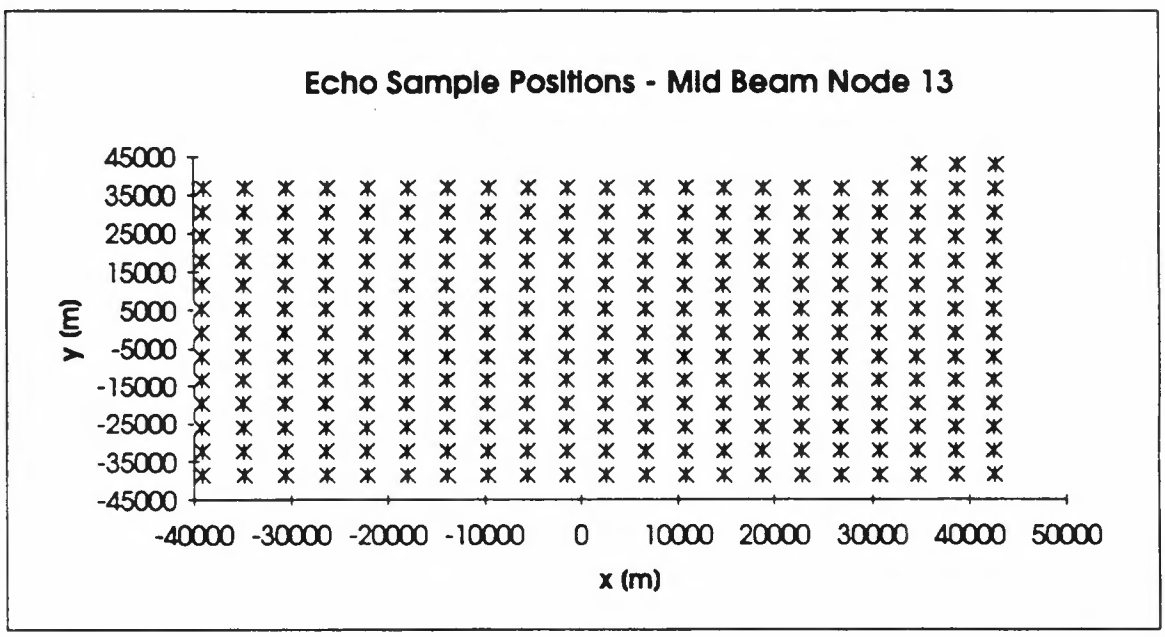
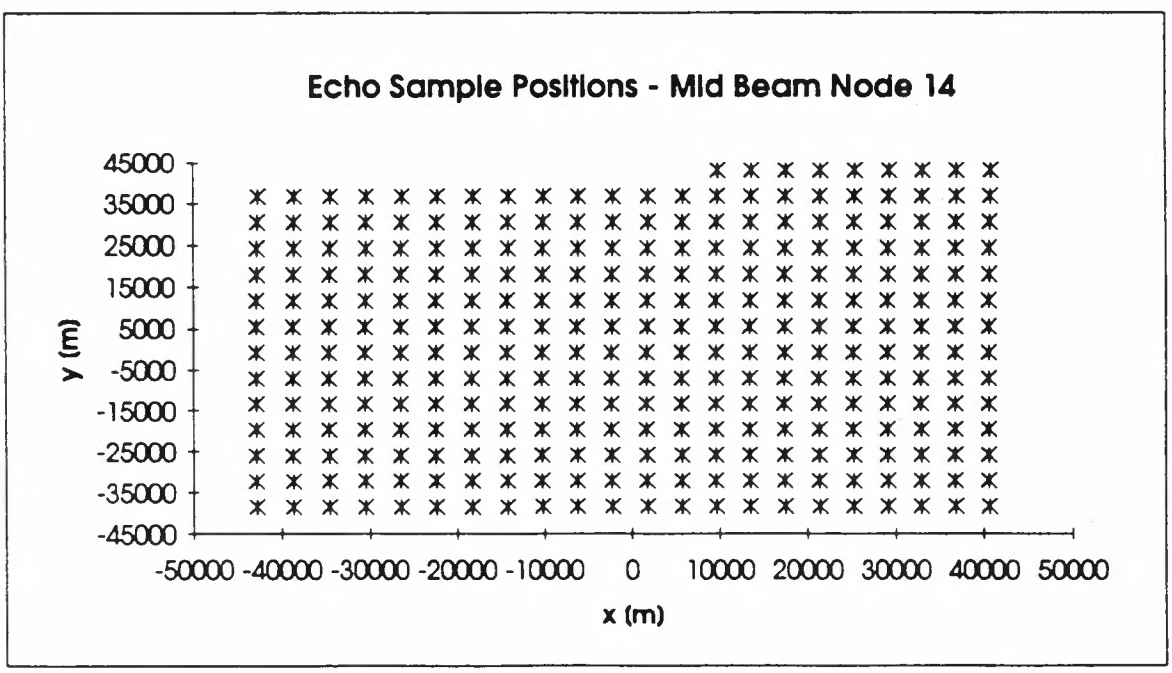


Figure A.5: Spatial Filter Weights, Δ CoG to Undisturbed Case in x- and y-Direction, Mid Beam, Filling Case


Echo Sample Positions - Mid Beam Node 12
y (m)
45000
35000
25000
15000
5000
-5000
-15000
-25000
-35000
-45000
-50000 -40000 -30000 -20000 -10000 0 10000 20000 30000 40000 50000
x (m)


Echo Sample Positions - Mid Beam Node 13
y (m)
45000
35000
25000
15000
5000
-5000
-15000
-25000
-35000
-45000
-40000 -30000 -20000 -10000 0 10000 20000 30000 40000 50000
x (m)


Echo Sample Positions - Mid Beam Node 14
y (m)
45000
35000
25000
15000
5000
-5000
-15000
-25000
-35000
-45000
-50000 -40000 -30000 -20000 -10000 0 10000 20000 30000 40000 50000
x (m)

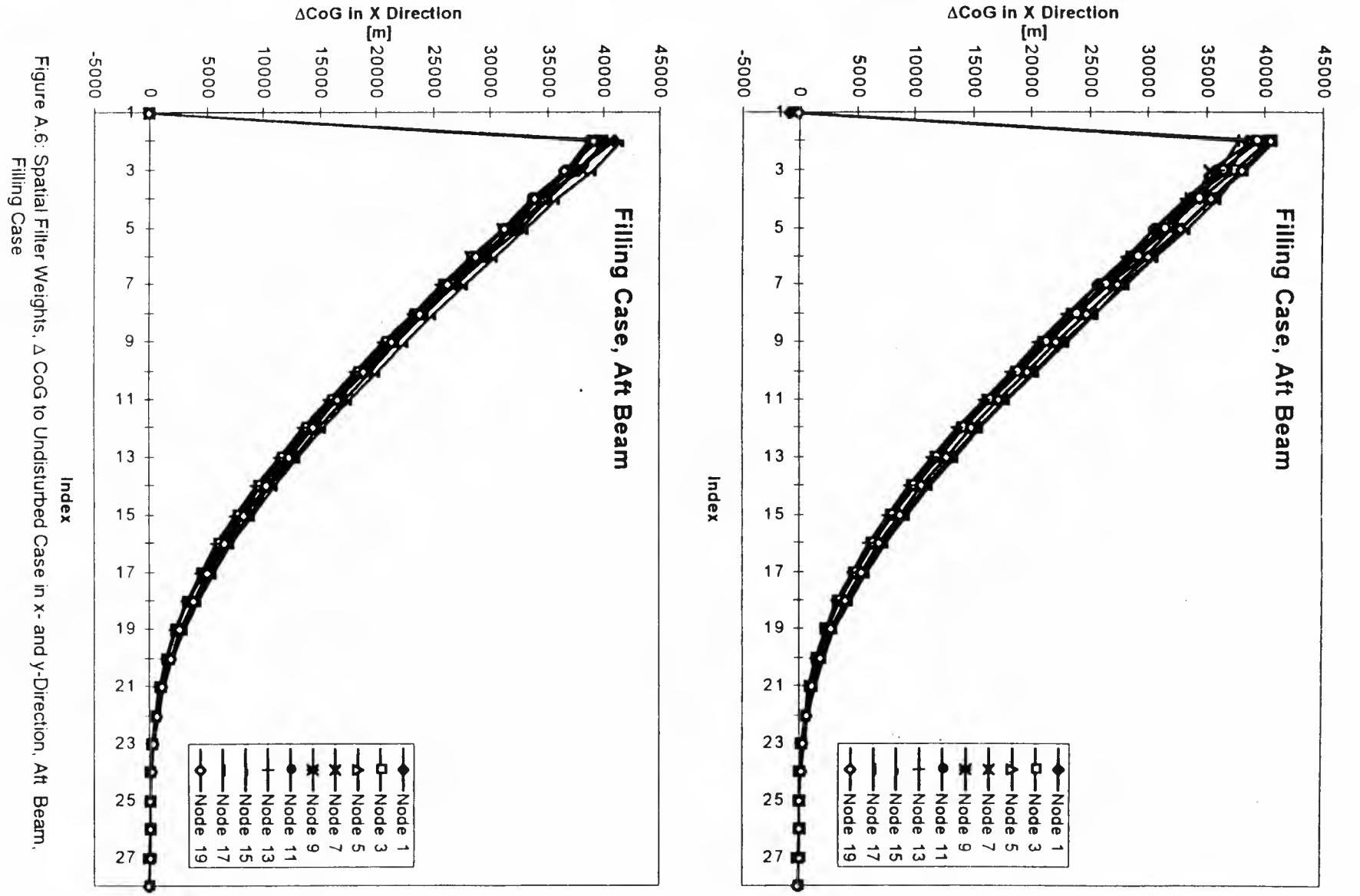


Figure A.6: Spatial Filter Weights, Δ CoG to Undisturbed Case in x- and y-Direction, Aft Beam, Filling Case

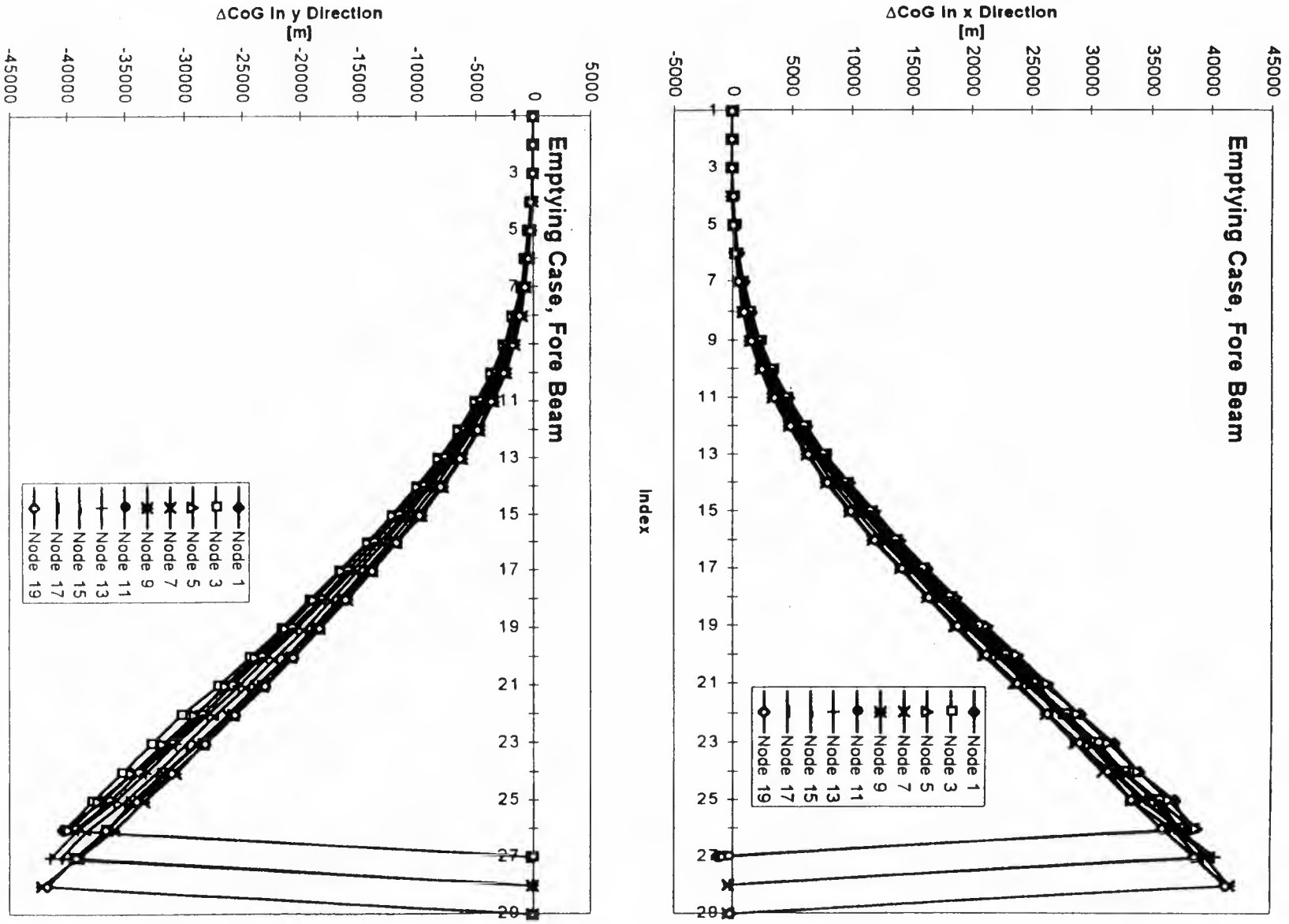
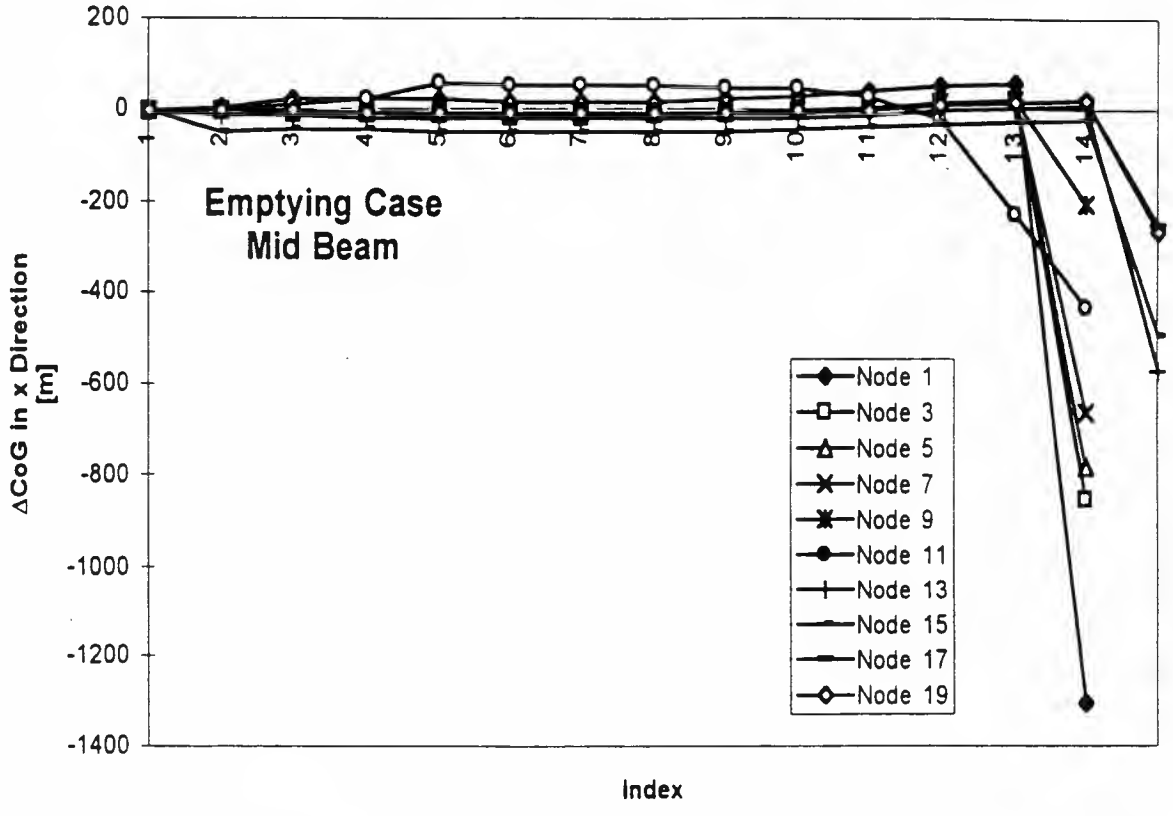


Figure A.7: Spatial Filter Weights, Δ CoG to Undisturbed Case in x- and y-Direction, Fore Beam, Emptying Case



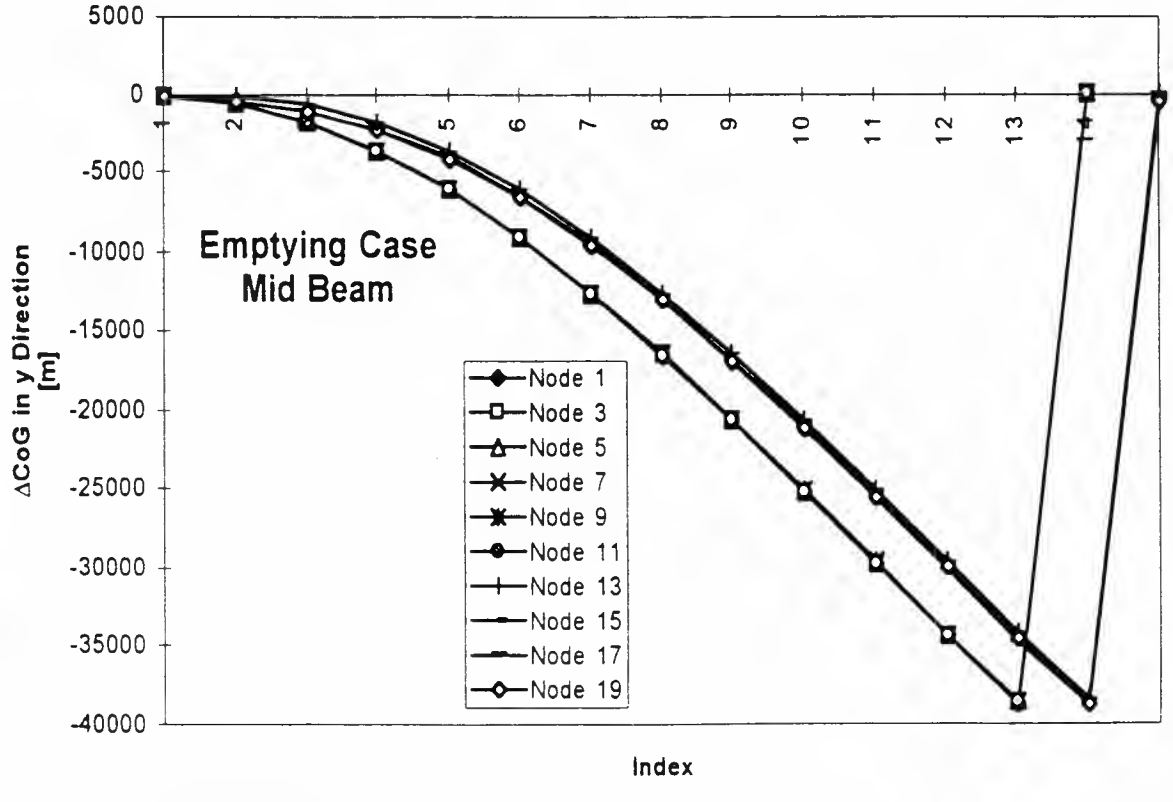
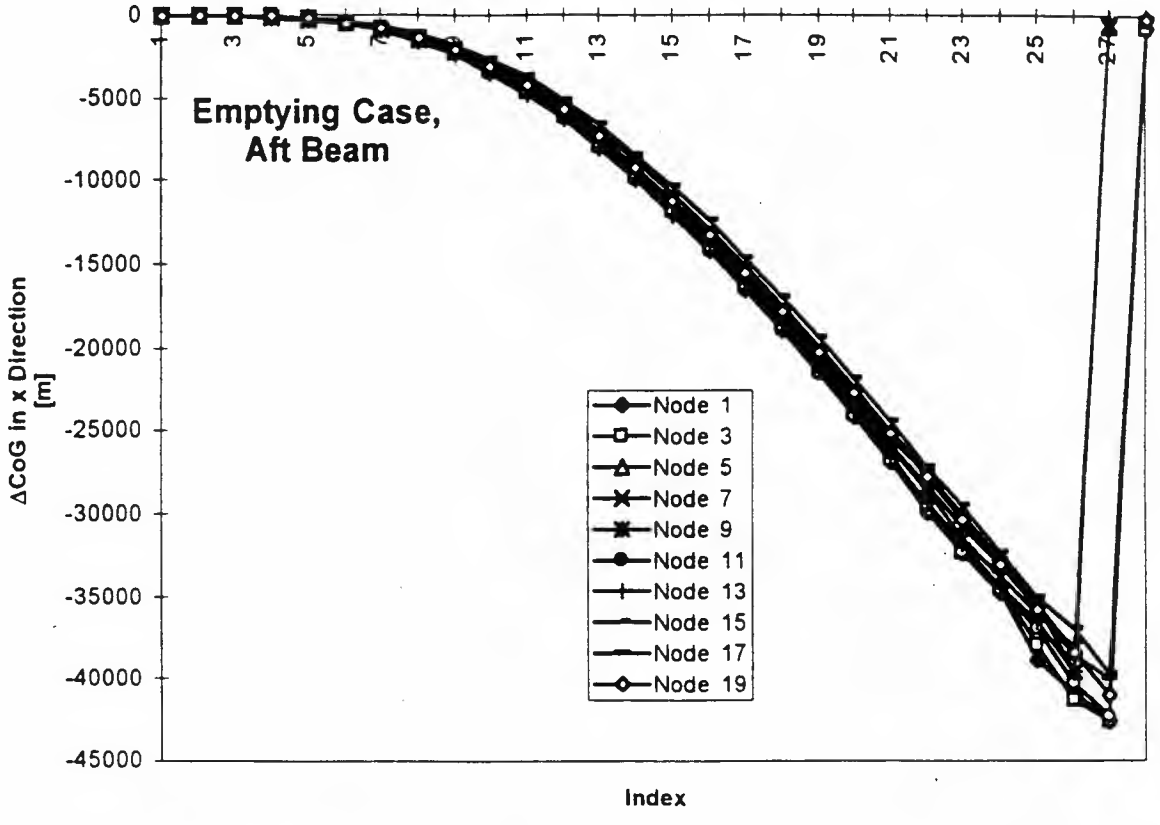


Figure A.8: Spatial Filter Weights, Δ CoG to Undisturbed Case in x- and y-Direction, Mid Beam, Emptying Case



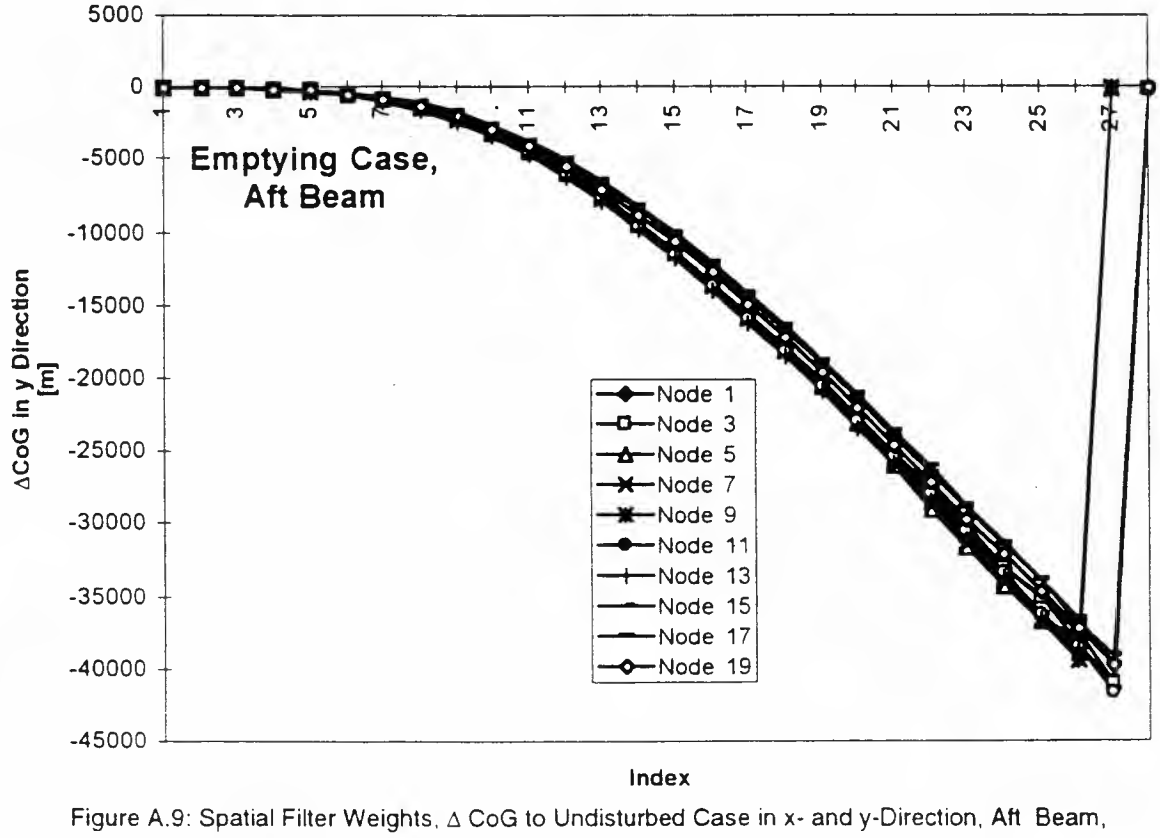


Figure A.9: Spatial Filter Weights, Δ CoG to Undisturbed Case in x- and y-Direction, Aft Beam, Emptying Case

3. Analysis of Effect on Spatial Filtering Process (5)

Facts about Incidence Angles:

- the incidence angle increases from near range to far range (node 1 to node 19)
- the rate of change of the incidence angle with position across track decreases across track.
- the range of incidence angles contributing to a node decreases across track
- the delta in incidence angle from the spatial filter near range boundary to the node is greater than from the node to its far range boundary.

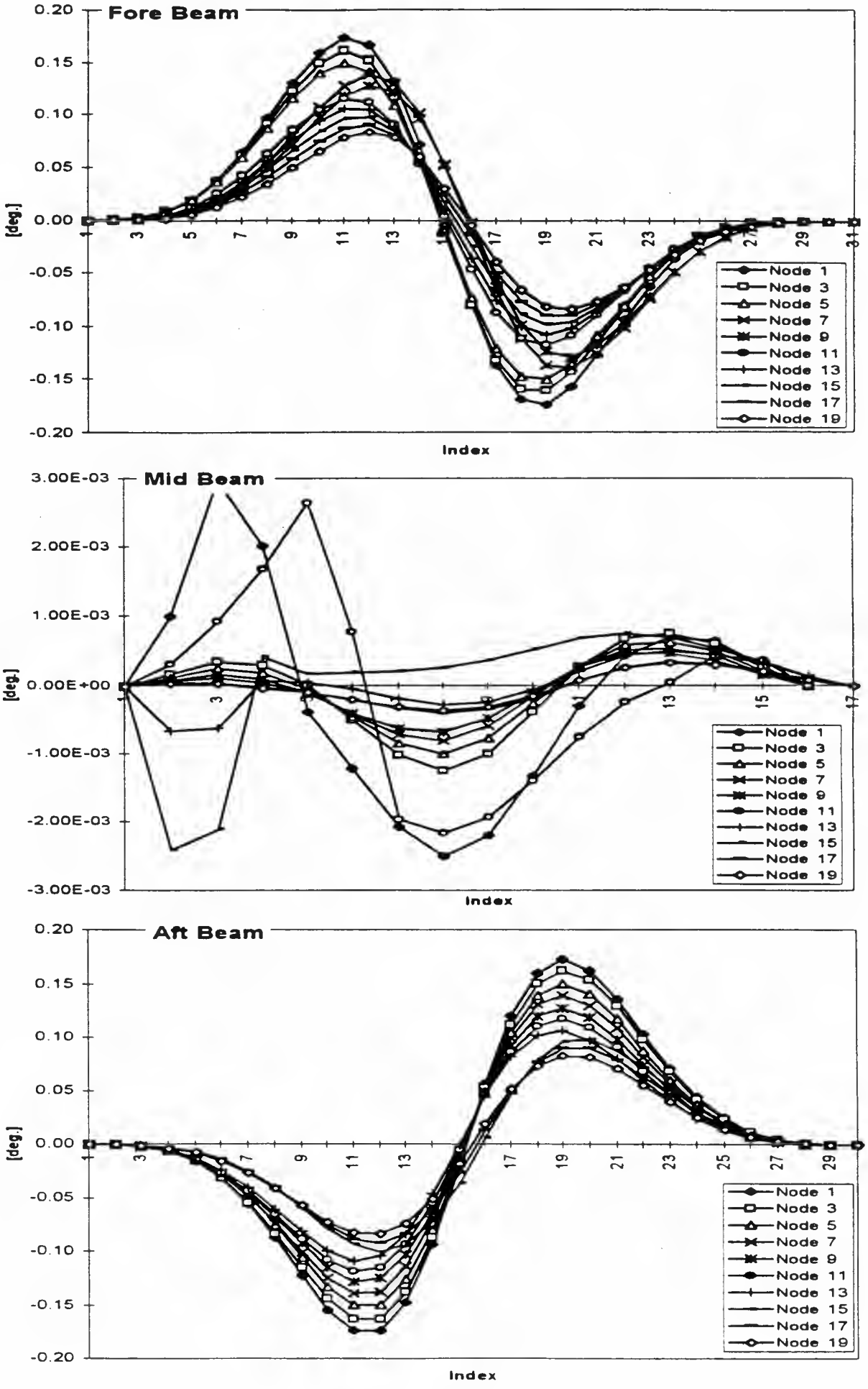


Figure B2: ΔCoG of Incidence Angle, Two Missing Blocks

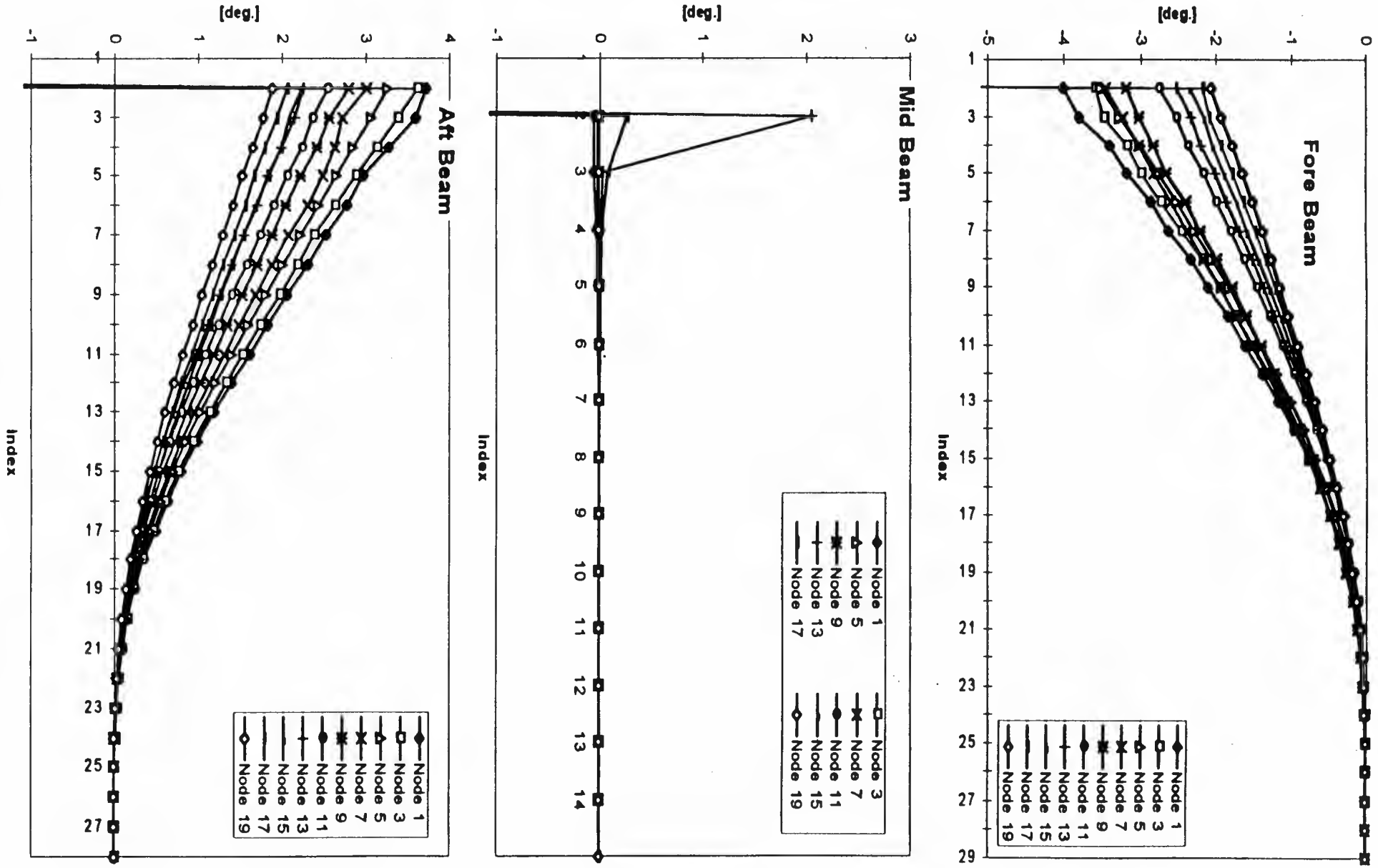
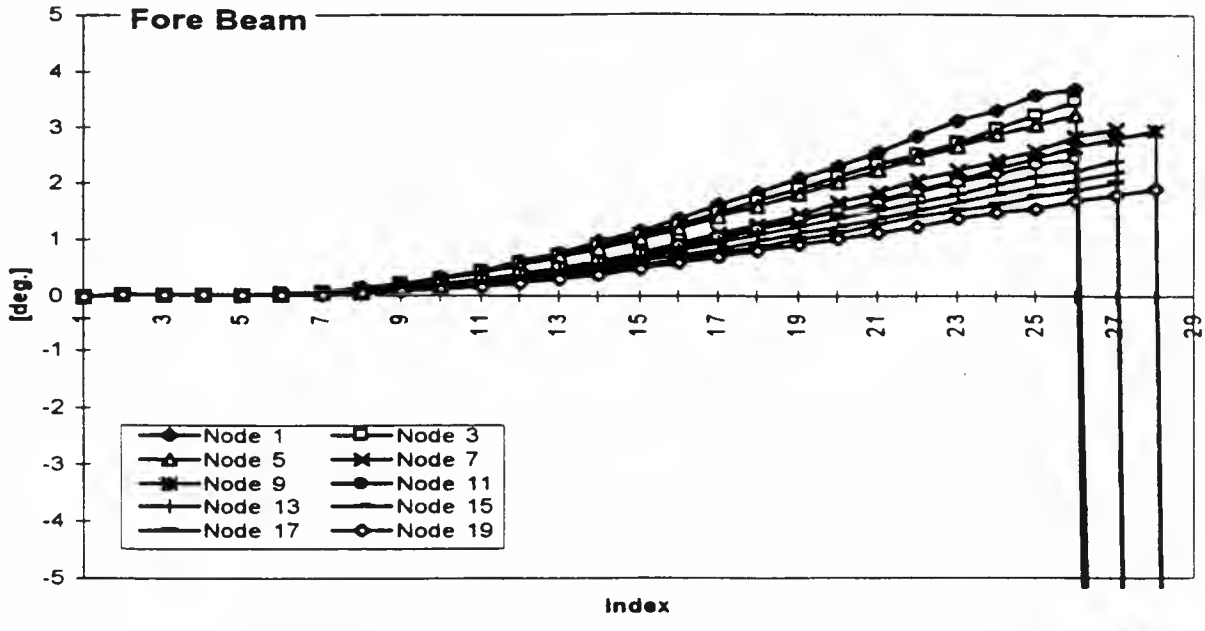
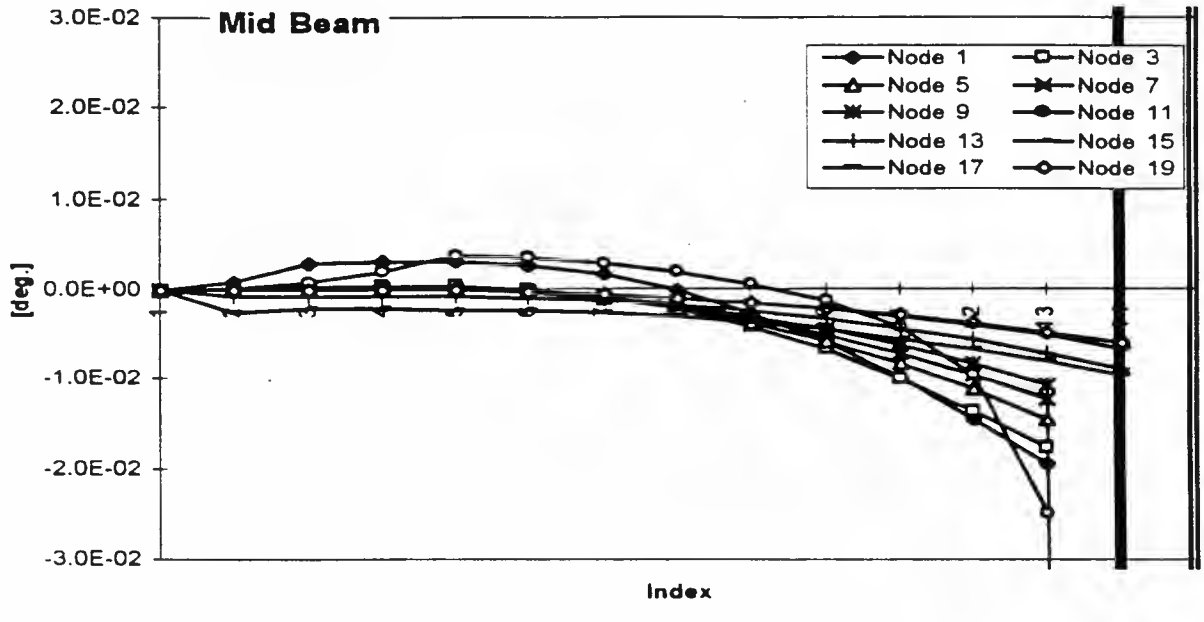


Figure B4: ΔCoG of Incidence Angle, Filling Case





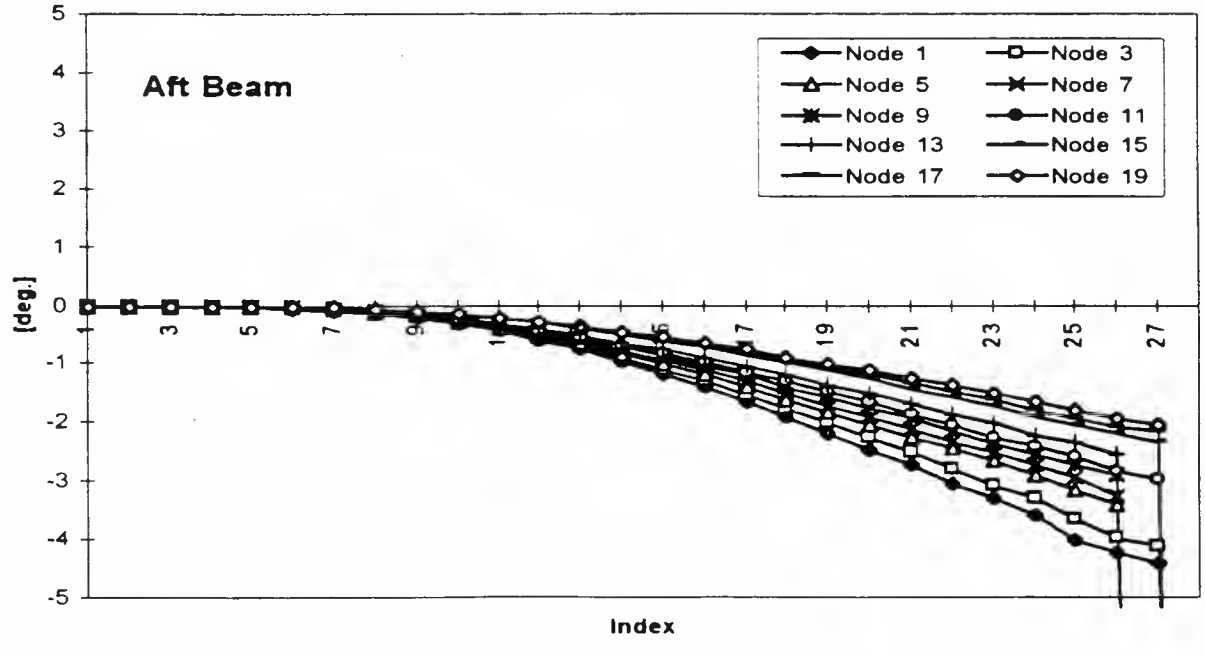


Figure B6: ΔCoG of Incidence Angle, Emptying Case

4. Analysis of Effect on the Complete Ground Processing (1)

Approach:

- to assess the impact of missing source packets including
  - all features of the raw data (speckle, instrument noise, quantisation noise and wind inhomogeneity)
  - all features of the ground processing steps (ADC non-linearity correction, internal calibration correction and spatial filtering)

  real AMI wind mode raw data (source packets) were processed for two swaths of approximately 2000km length using the ground processing mode of the Scatterometer System Simulator.
- wind mode data without missing source packets were used as reference
- source packets were artificially deleted to simulate wind/wave mode and instrument switch on/off.

4. Analysis of Effect on the Complete Ground Processing (2)

Data used for the analysis:

- only very limited number of wind mode raw data available
- only two sequences of sufficient length over open ocean could be identified in available data set:

  - scene 1, which was acquired on the 22. August 1991 at 14.14 to 14.25 hours at a position 2550 sec after ascending node crossing, which is on the descending path off the American east coast (figures are referenced as Fx).

  - scene 2, which was acquired on the 22. August 1991 at 14.58 to 15.08 hours at a position 850 sec before ascending node crossing, which is on the ascending path south-west of Australia (figures are referenced as Gx).

4. Analysis of Effect on the Complete Ground Processing (3) - Scene 1

Undisturbed case shows

- incidence angle dependent drop of σ^0 across track
- rather strong variation along track (non-constant wind)

Wind/wave mode case shows

- orientation of effect along antenna pointing direction
- for node 1
  - in general behaviour as expected from spatial filter analysis
  - significant deviation around node 75 due to strong along track variation of σ^0
- for nodes 11 and 19
  - pattern observed in spatial filter analysis less visible
  - effect of along track variation of σ^0 and statistical effects are dominating
- for mid beam
  - due to the measurement geometry, the spatial filtering of four out of eight along track rows of nodes is not affected by the missing source packets
  - effect observed in these nodes caused by 'memory' of internal calibration correction factor calculation (strong quantization noise of samples - appr. 3%)

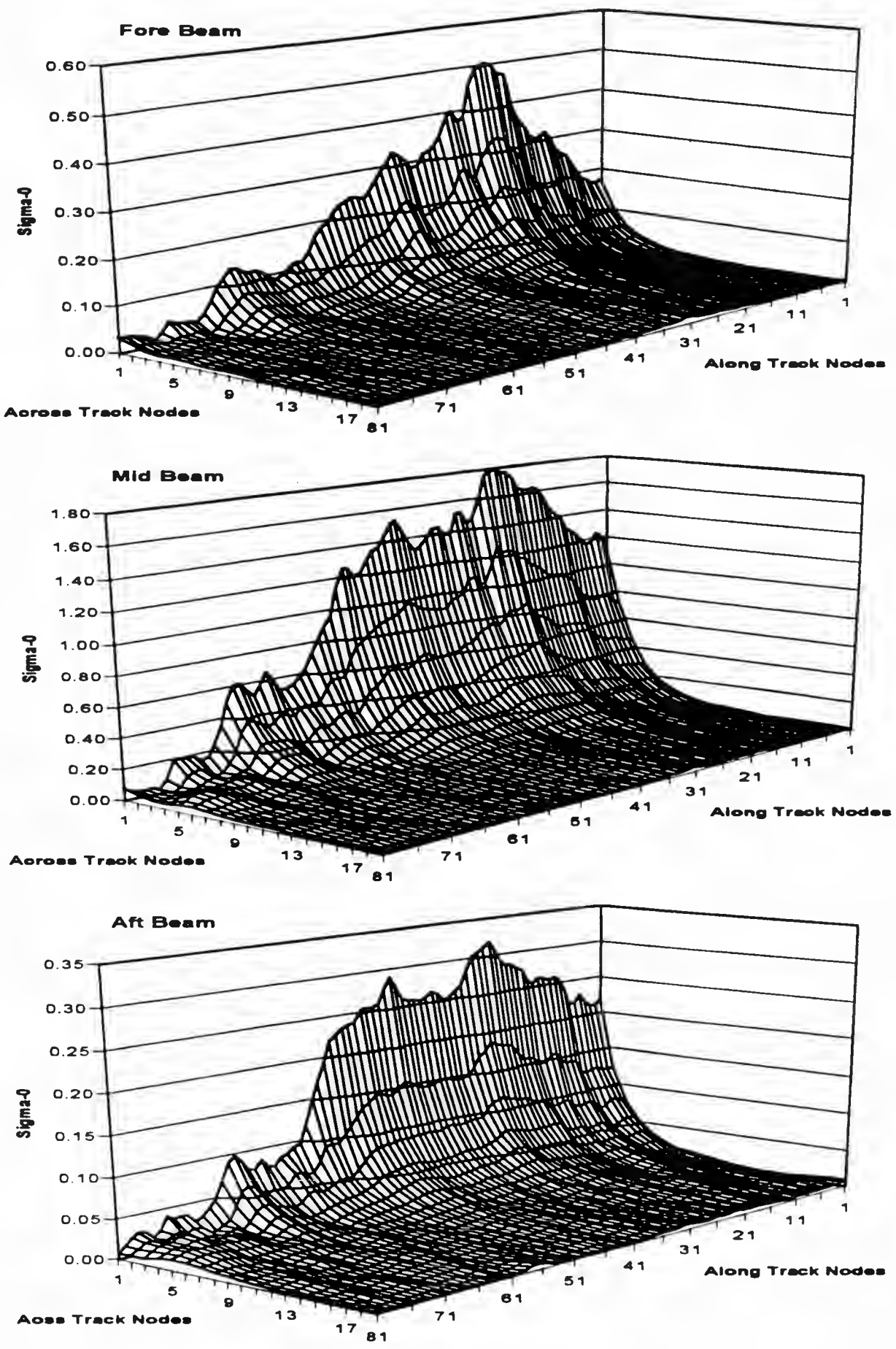


Figure F1: Undisturbed Sigma-0 Product for Scene 1

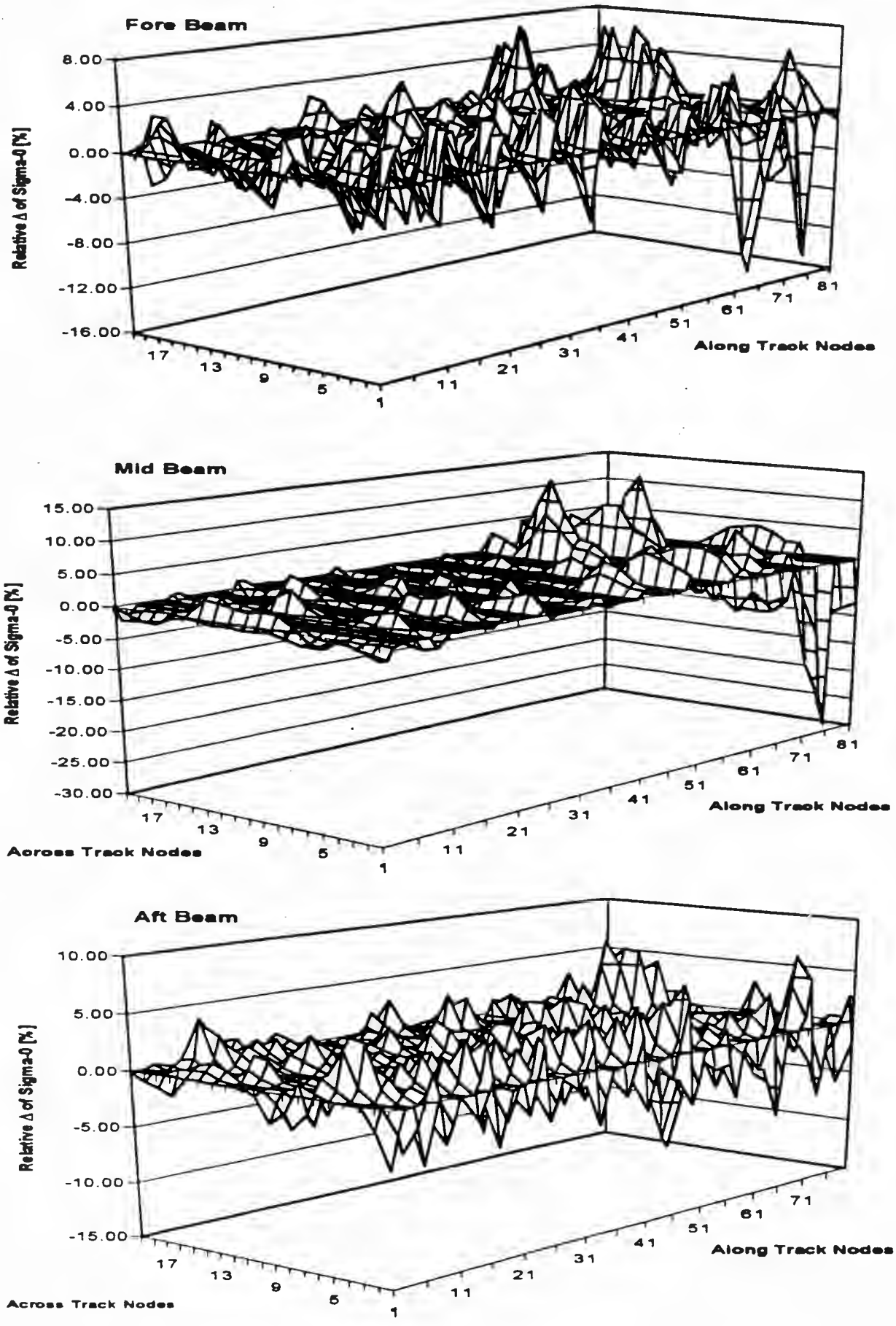


Figure F2: Relative Difference of Sigma-0 Products (Wind/Wave Mode vs. Wind Mode Sequenc

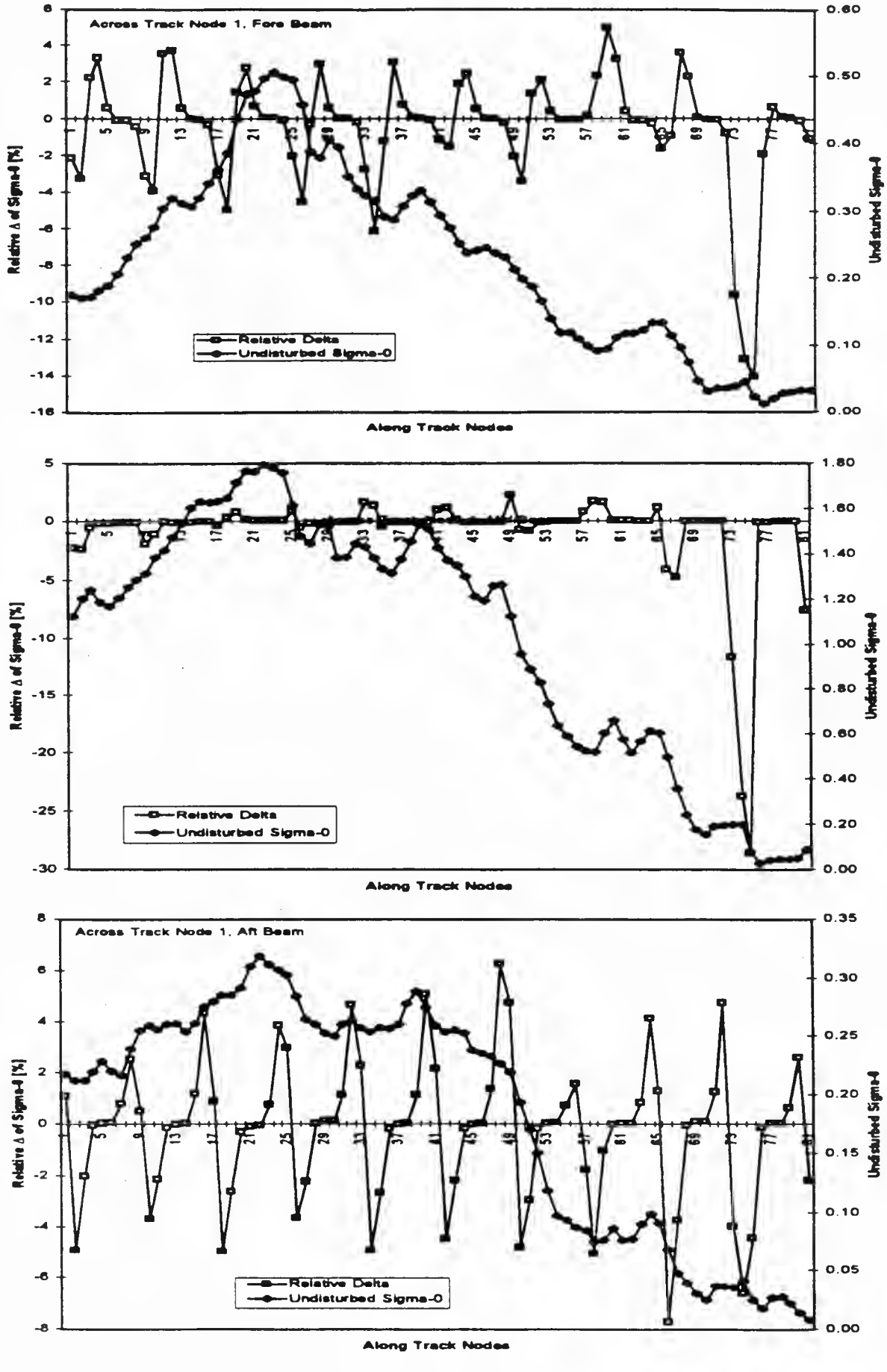
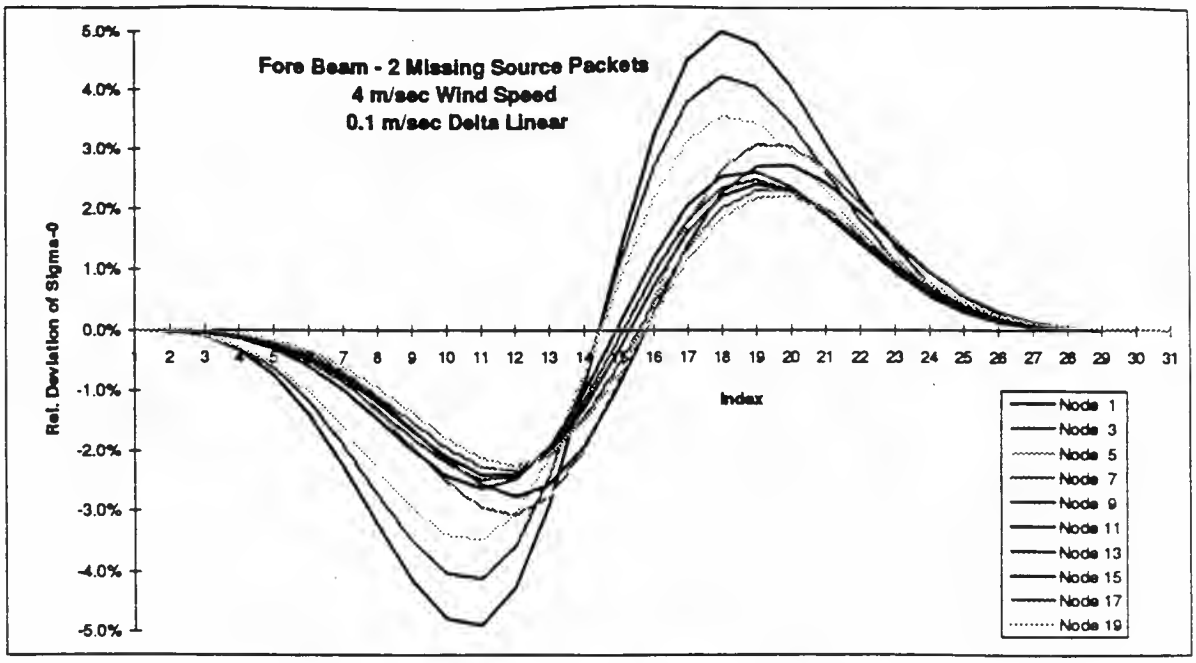
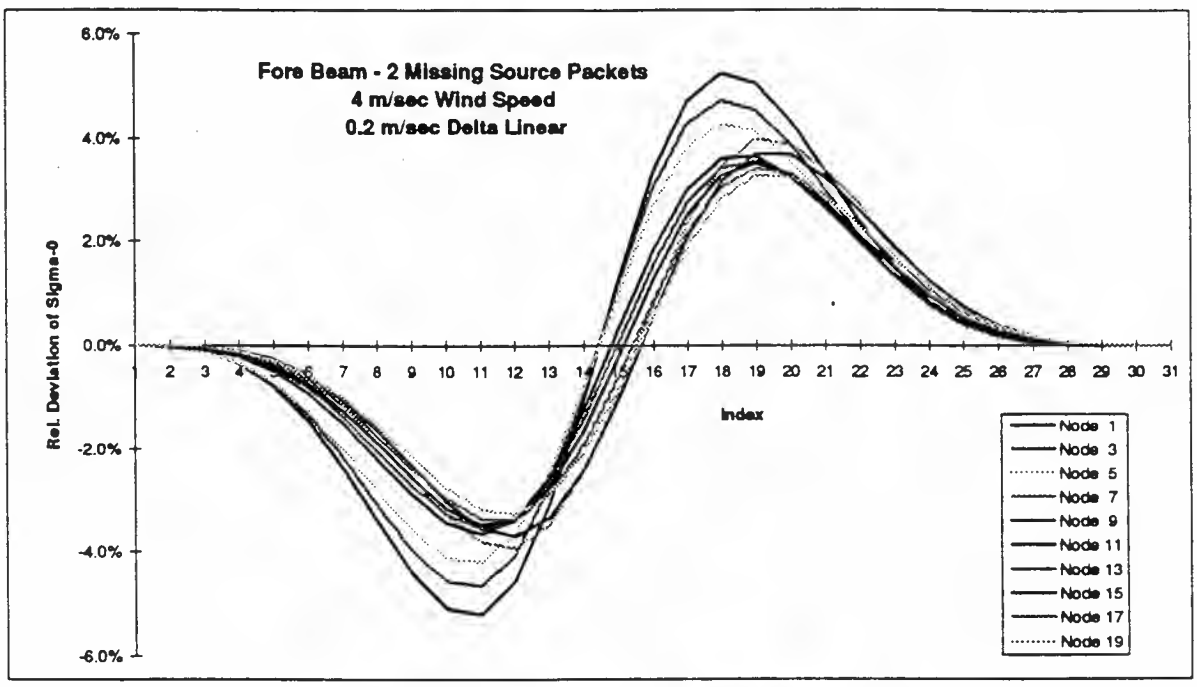
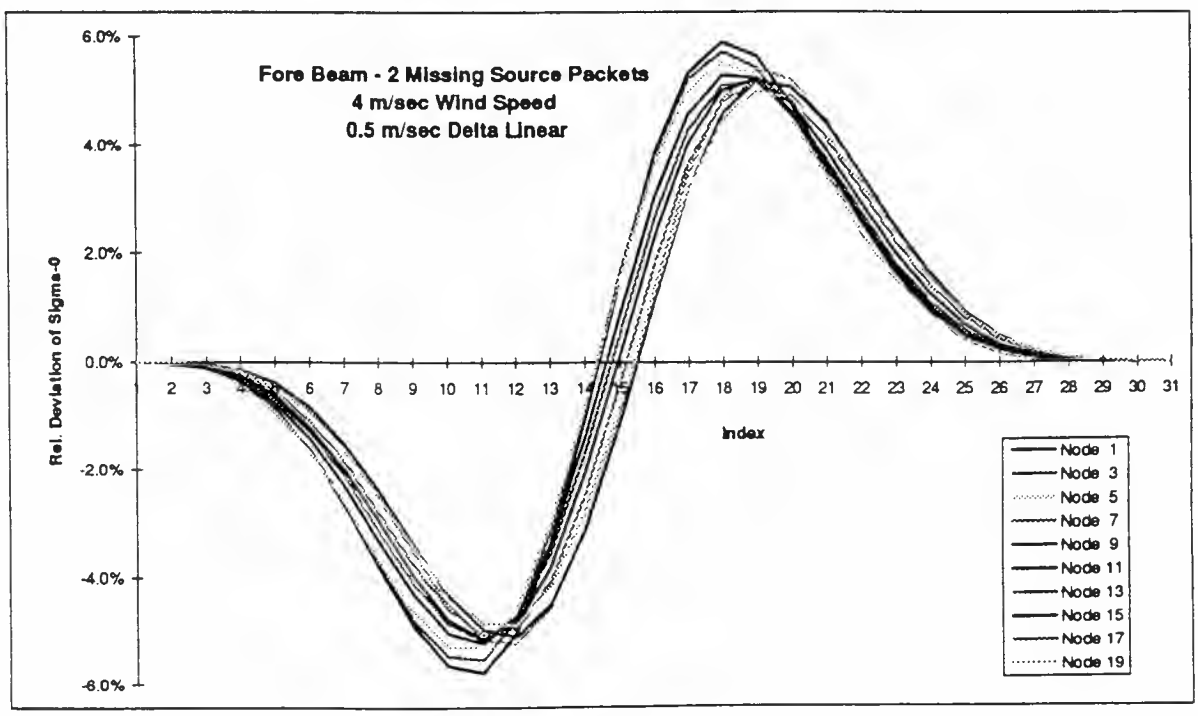


Figure F3: Deviation of Wind/Wave Mode Product for Across Track Node 1

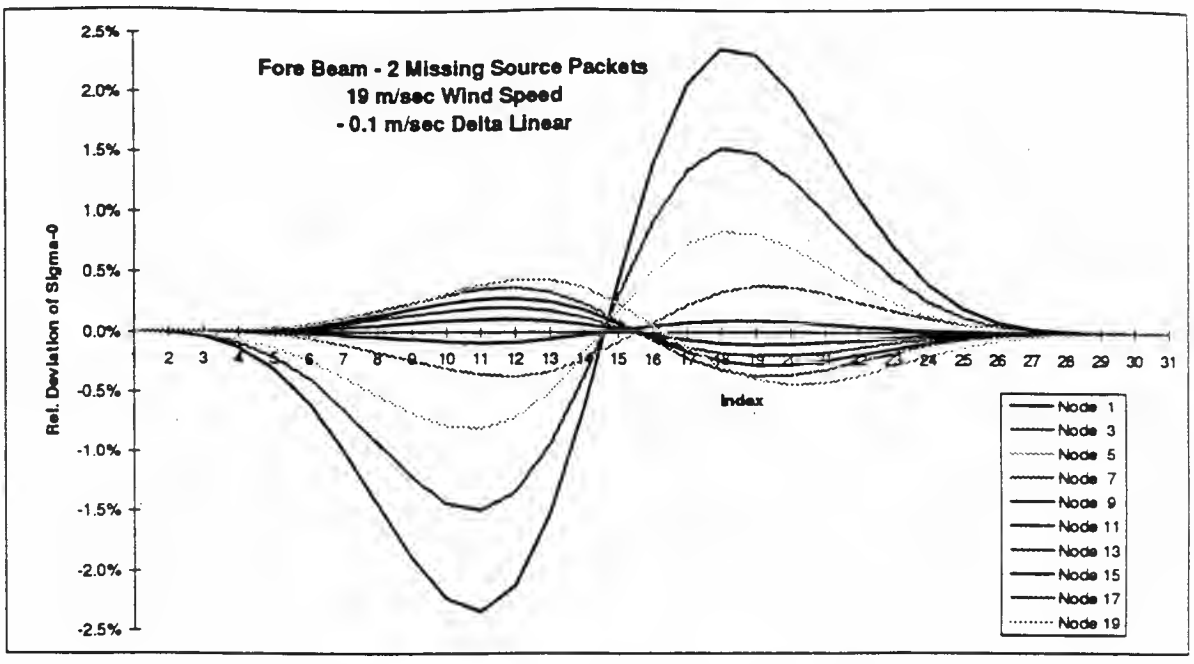

Fore Beam - 2 Missing Source Packets
4 m/sec Wind Speed
0.1 m/sec Delta Linear
Rel. Deviation of Sigma-0
Index
Node 1
Node 3
Node 5
Node 7
Node 9
Node 11
Node 13
Node 15
Node 17
Node 19

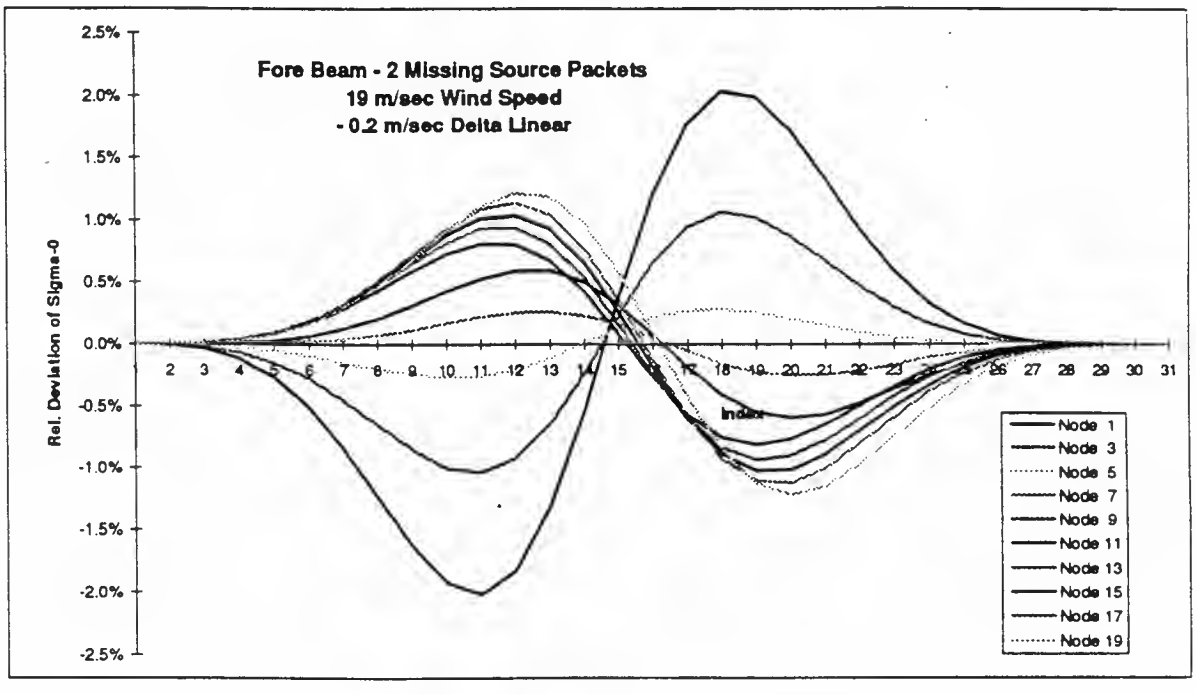

Fore Beam - 2 Missing Source Packets
4 m/sec Wind Speed
0.2 m/sec Delta Linear
Rel. Deviation of Sigma-0
Index
Node 1
Node 3
Node 5
Node 7
Node 9
Node 11
Node 13
Node 15
Node 17
Node 19

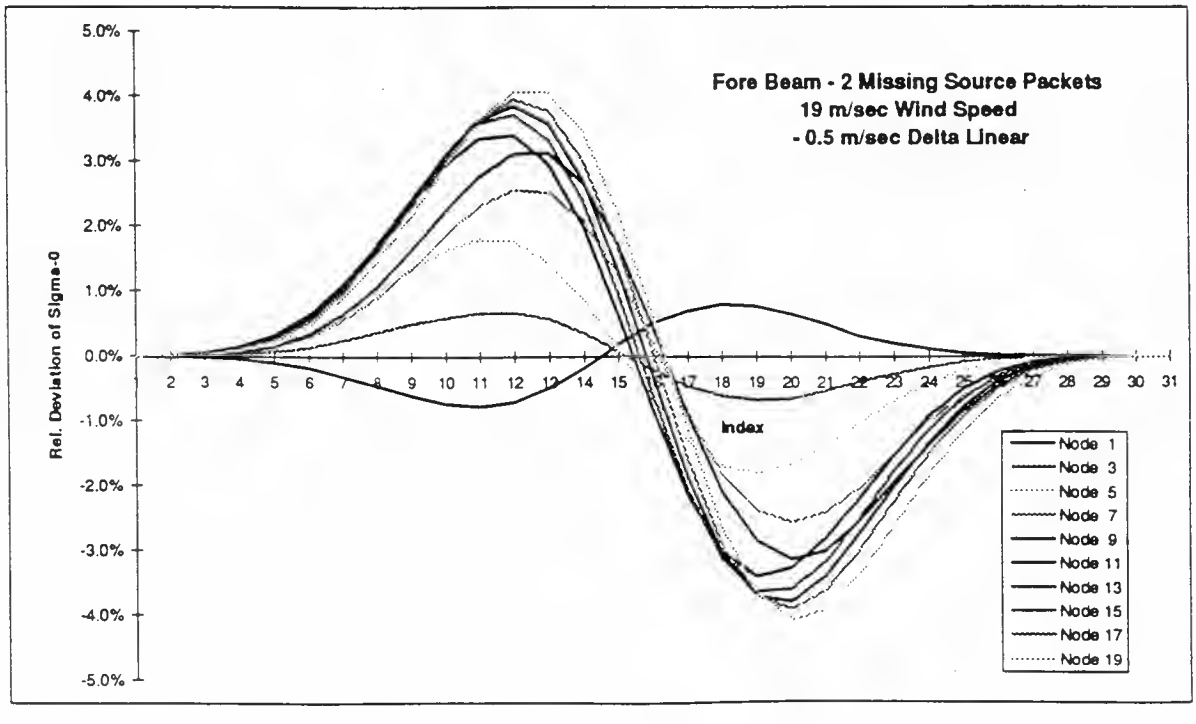

Fore Beam - 2 Missing Source Packets
4 m/sec Wind Speed
0.5 m/sec Delta Linear
Rel. Deviation of Sigma-0
Index
Node 1
Node 3
Node 5
Node 7
Node 9
Node 11
Node 13
Node 15
Node 17
Node 19

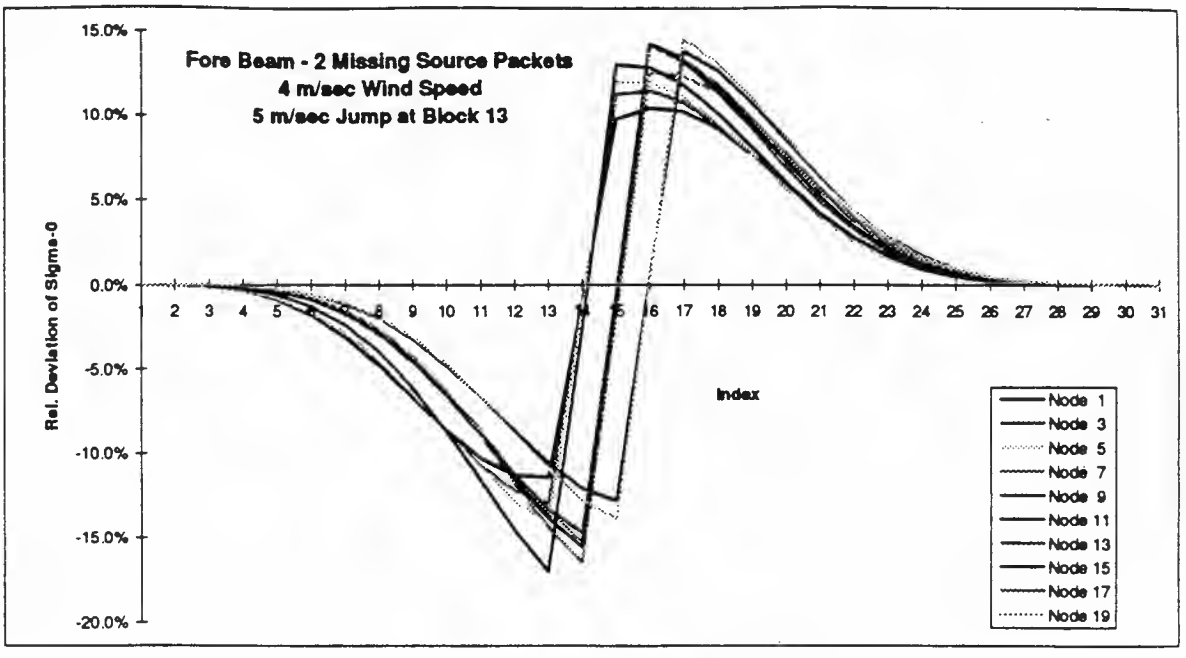
Daimler-Benz Aerospace
Dornier

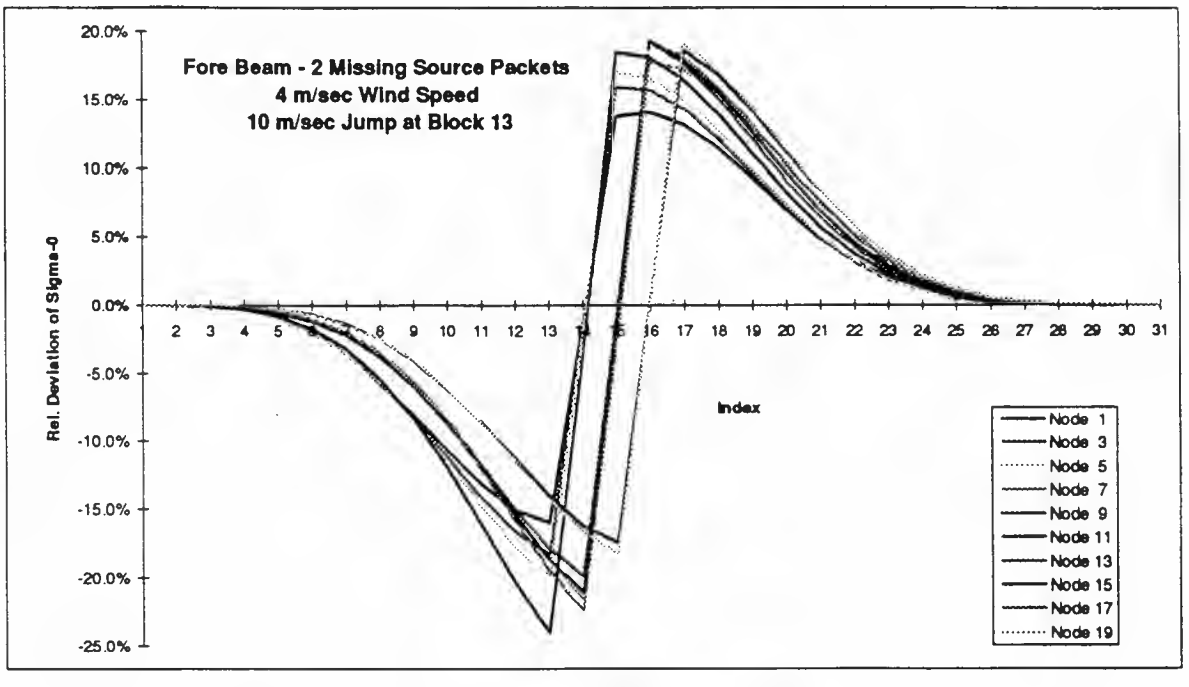
Scatterometer Missing Source Packets Study

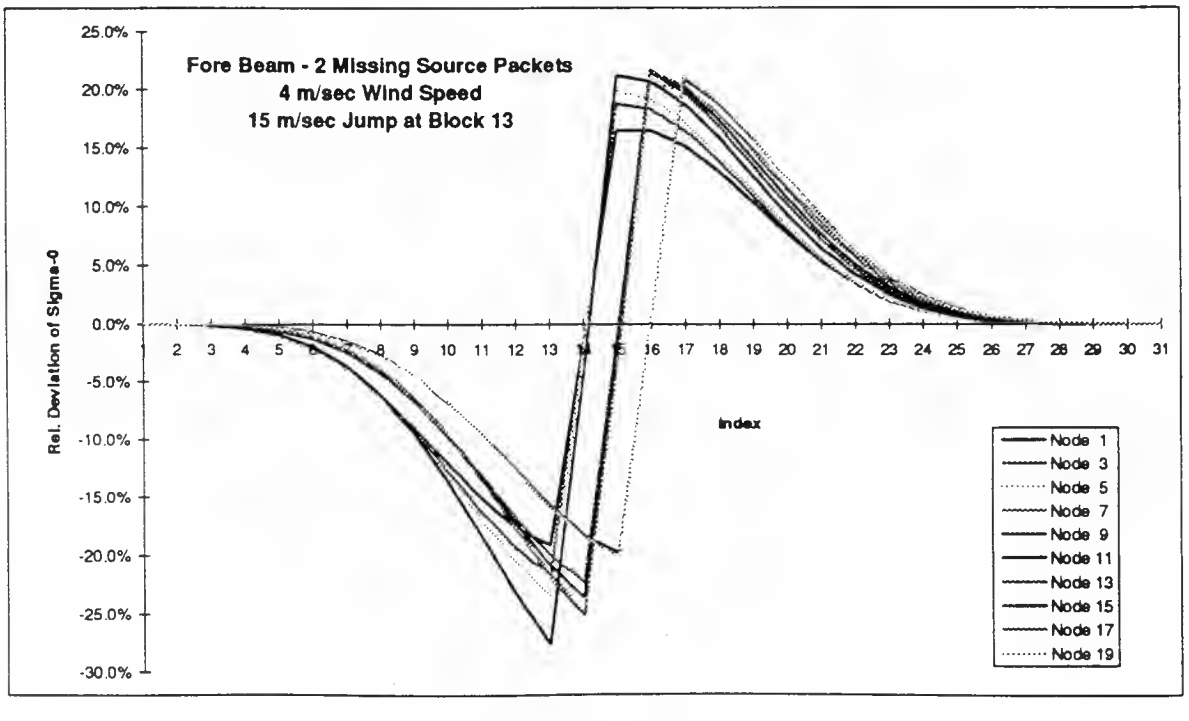




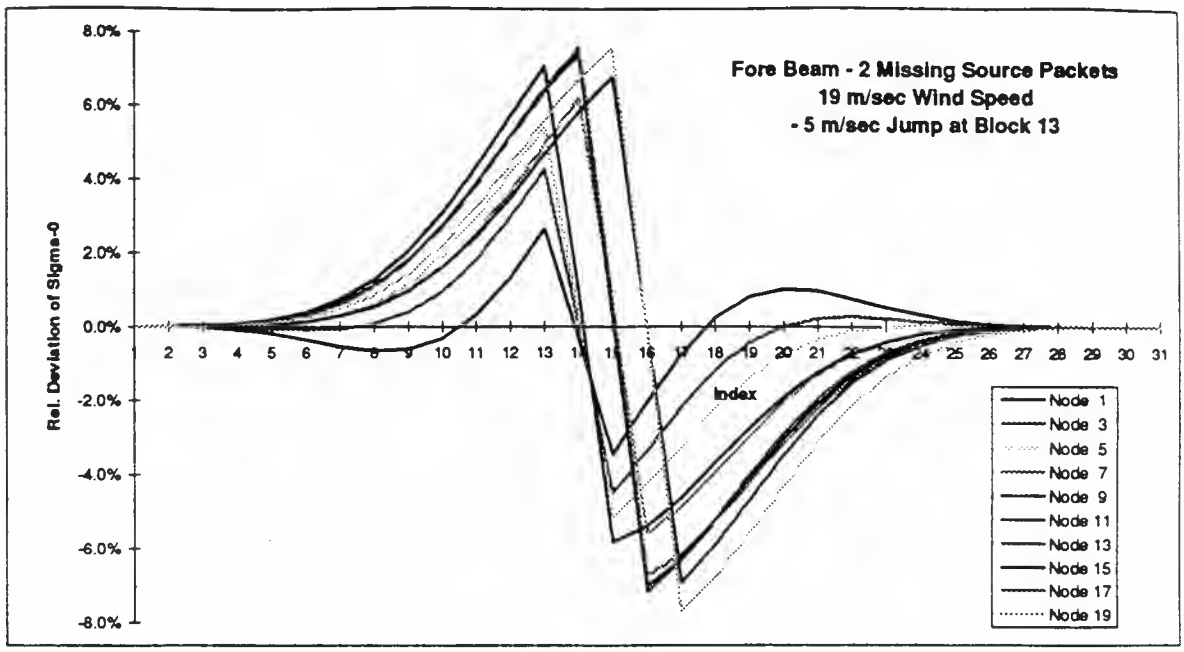


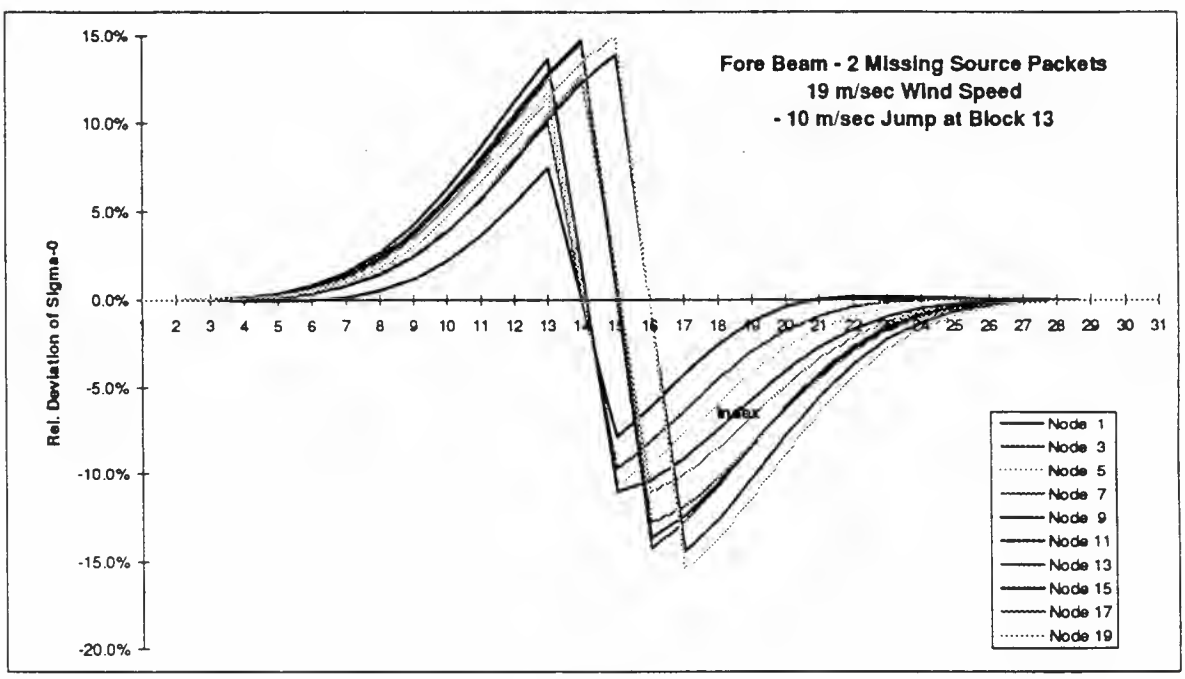

Fore Beam - 2 Missing Source Packets
4 m/sec Wind Speed
5 m/sec Jump at Block 13
Rel. Deviation of Sigma-0
Index
Node 1
Node 3
Node 5
Node 7
Node 9
Node 11
Node 13
Node 15
Node 17
Node 19

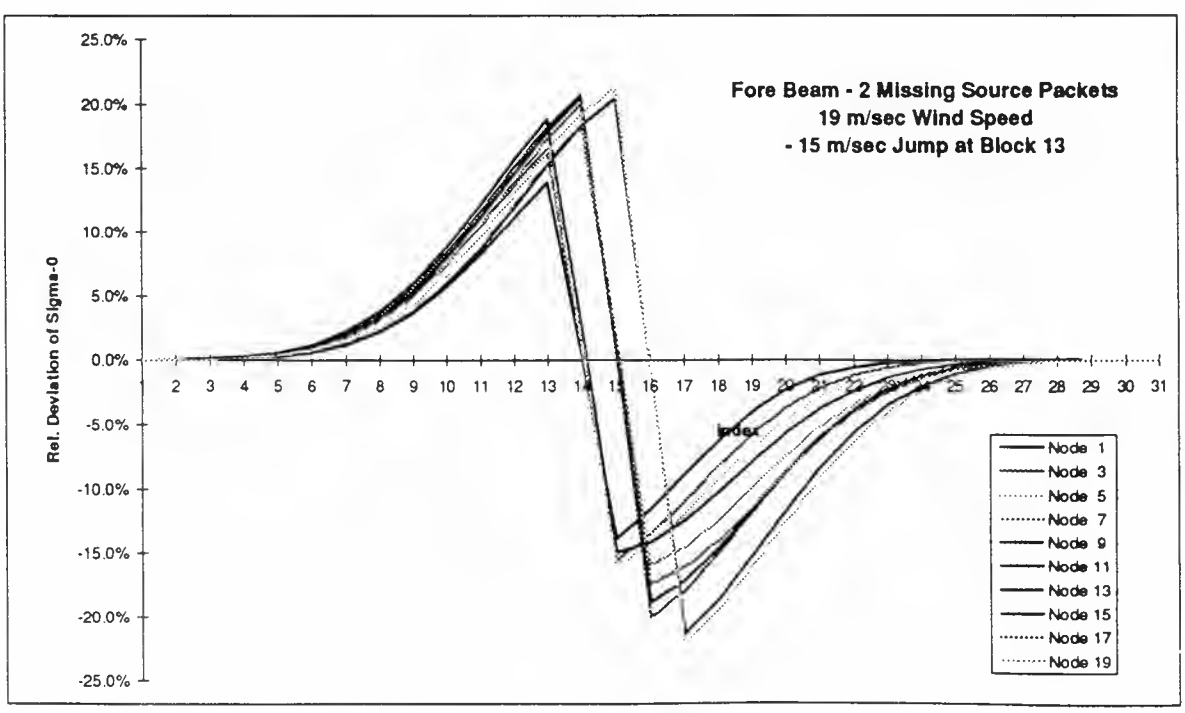

Fore Beam - 2 Missing Source Packets
4 m/sec Wind Speed
10 m/sec Jump at Block 13
Rel. Deviation of Sigma-0
Index
Node 1
Node 3
Node 5
Node 7
Node 9
Node 11
Node 13
Node 15
Node 17
Node 19


Fore Beam - 2 Missing Source Packets
4 m/sec Wind Speed
15 m/sec Jump at Block 13
Rel. Deviation of Sigma-0
Index
Node 1
Node 3
Node 5
Node 7
Node 9
Node 11
Node 13
Node 15
Node 17
Node 19

Scatterometer Missing Source Packets Study

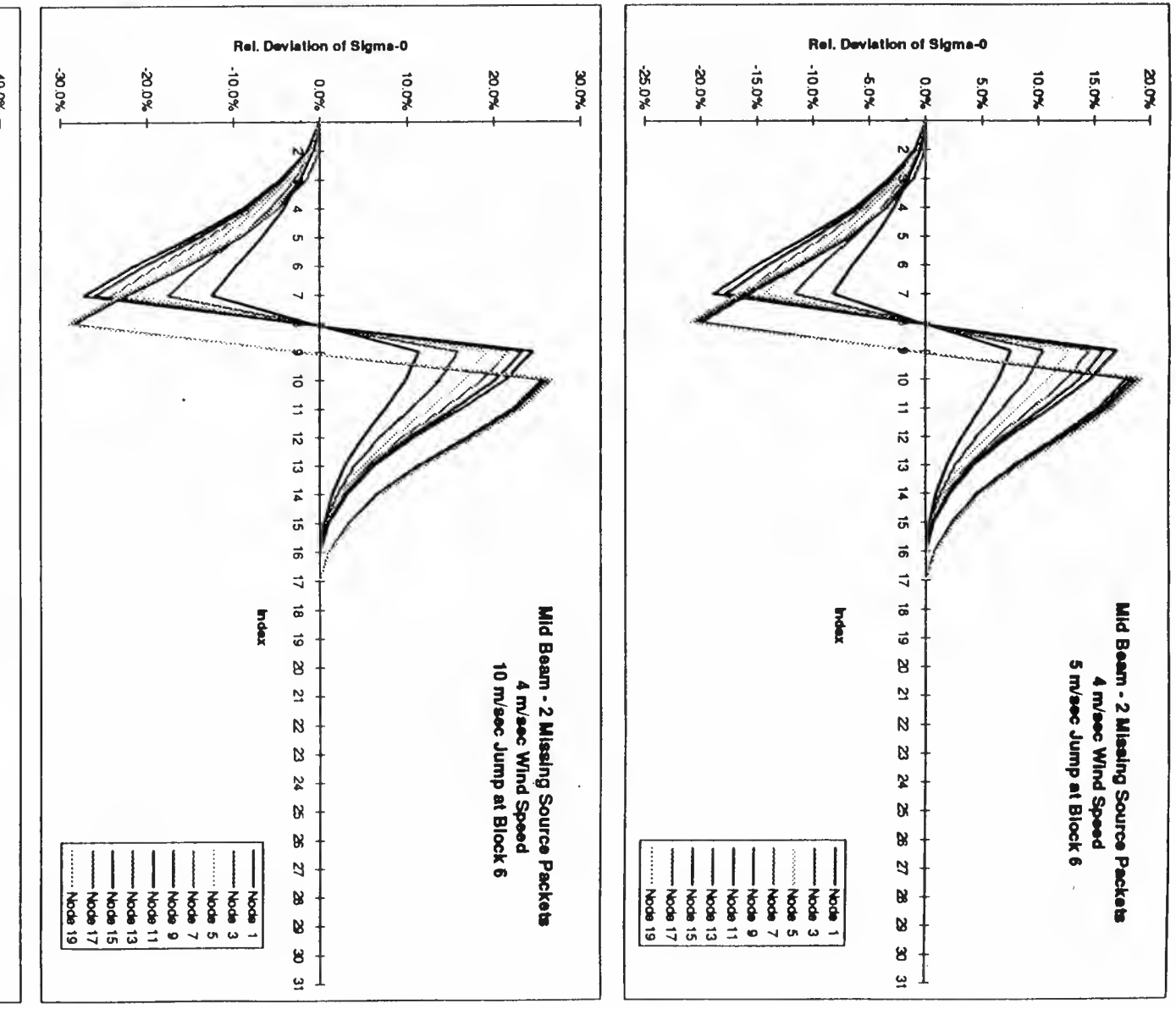


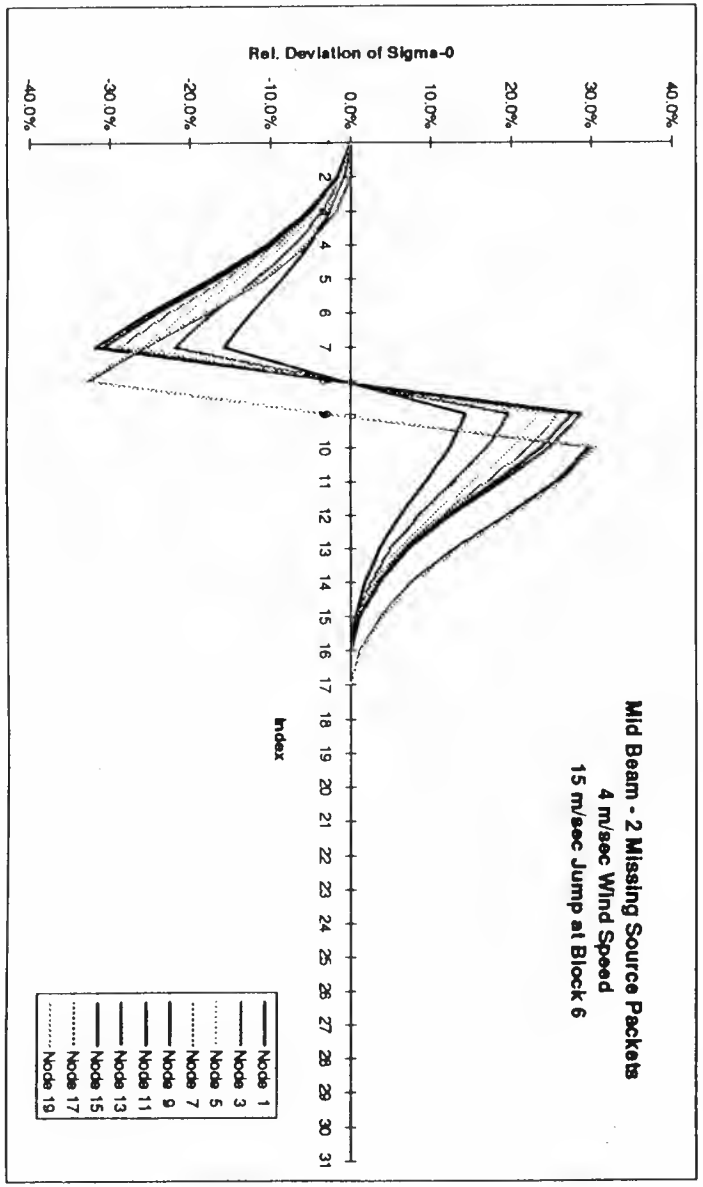




Scatterometer Missing Source Packets Study

Daimler-Benz Aerospace
Dornier





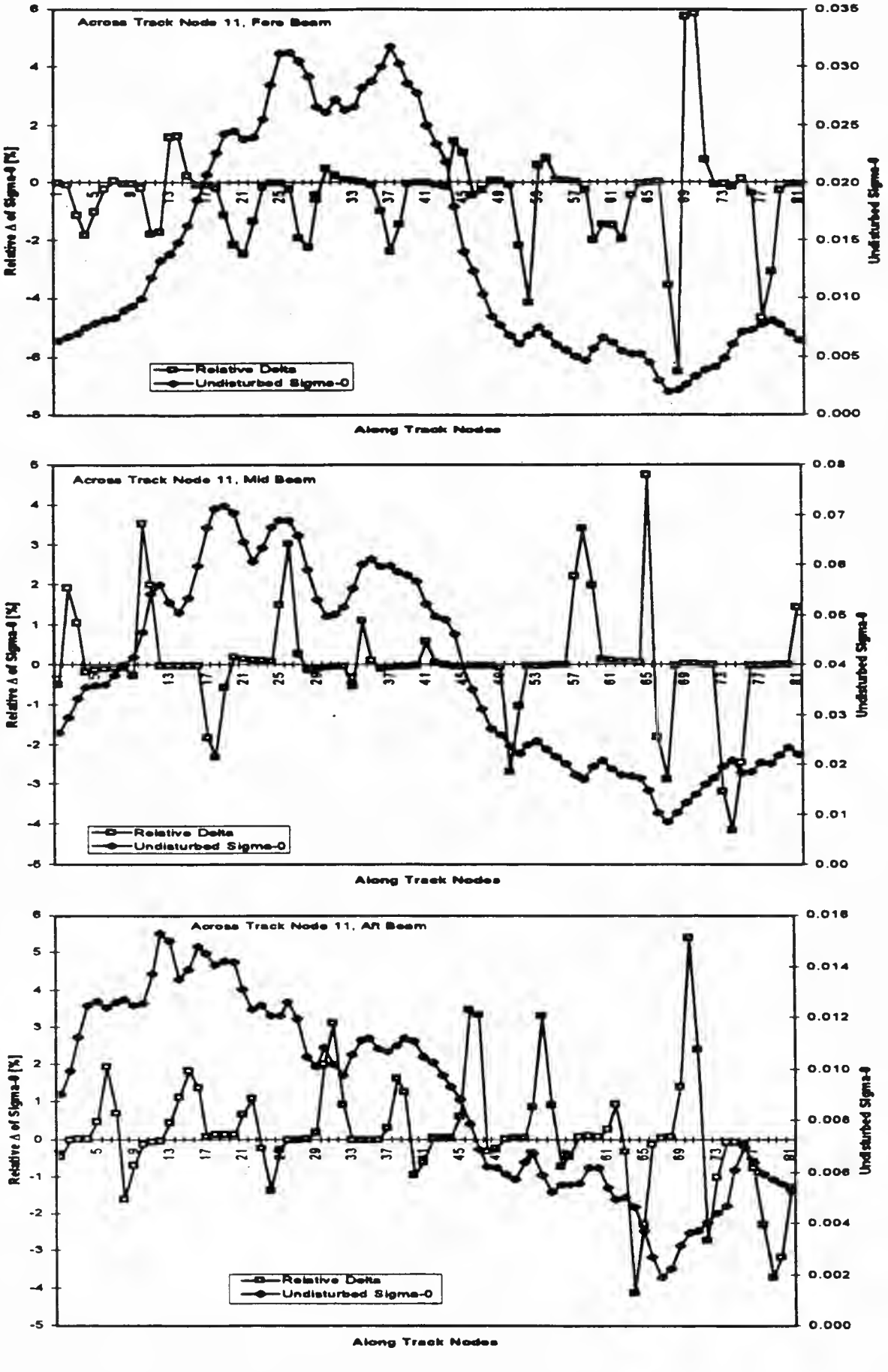


Figure F4: Deviation of Wind/Wave Mode Product for Across Track Node 11

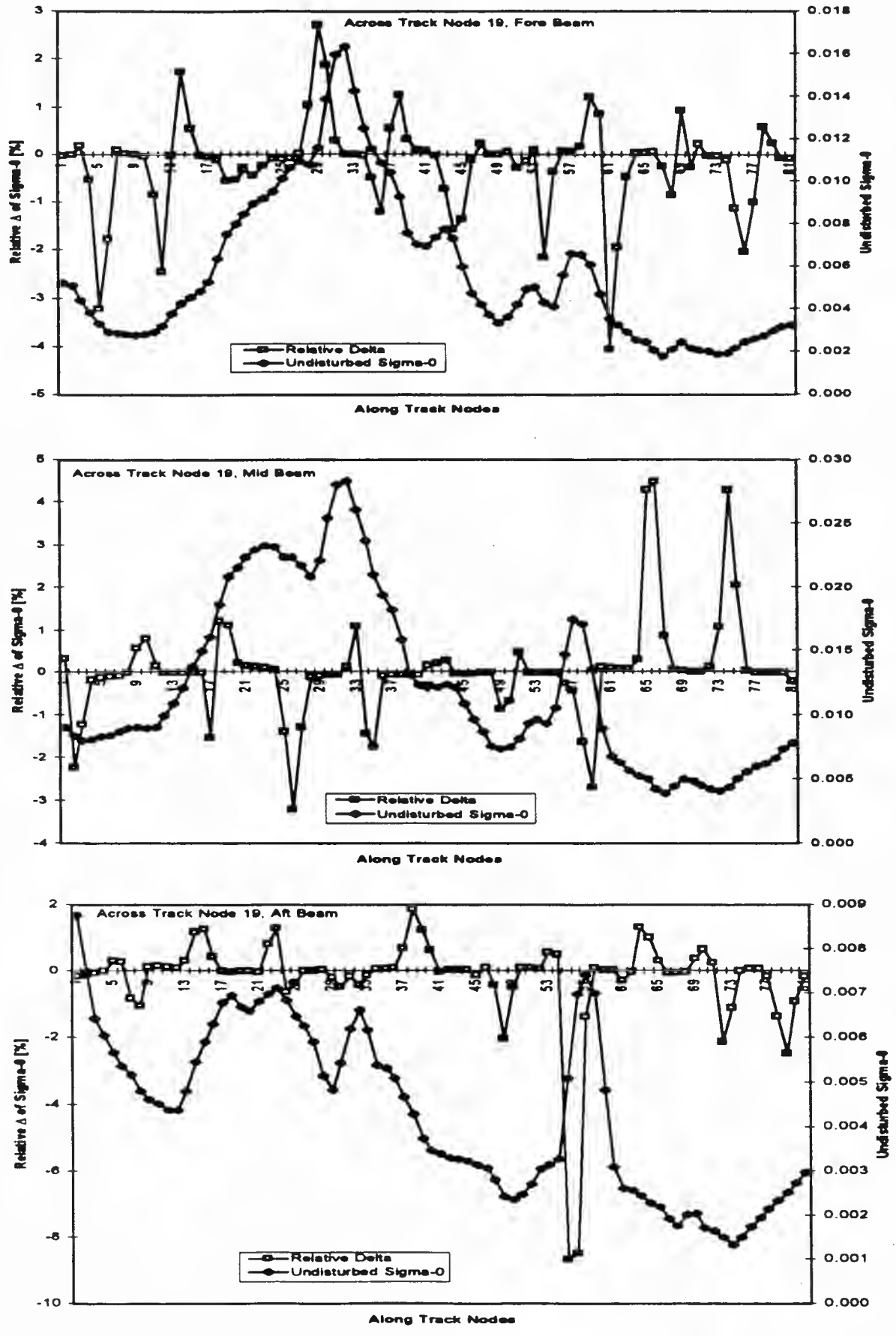


Figure F5: Deviation of Wind/Wave Mode Product for Across Track Node 19

4. Analysis of Effect on the Complete Ground Processing (4) - Scene 1

The instrument switch-on case shows

- orientation of effect along antenna pointing direction
- in general behaviour as expected from spatial filter analysis
- significant deviation fro aft beam, node 19, due to strong along track variation of σ^0
- the processing steps with memory (ADC non-linearity correction, internal calibration correction) have to stabilize. This is clearly visible for mid and aft beam.

The instrument switch-off case shows

- in general the same effects as the instrument switch-on case
- a settling of processing steps with memory does of course not occur

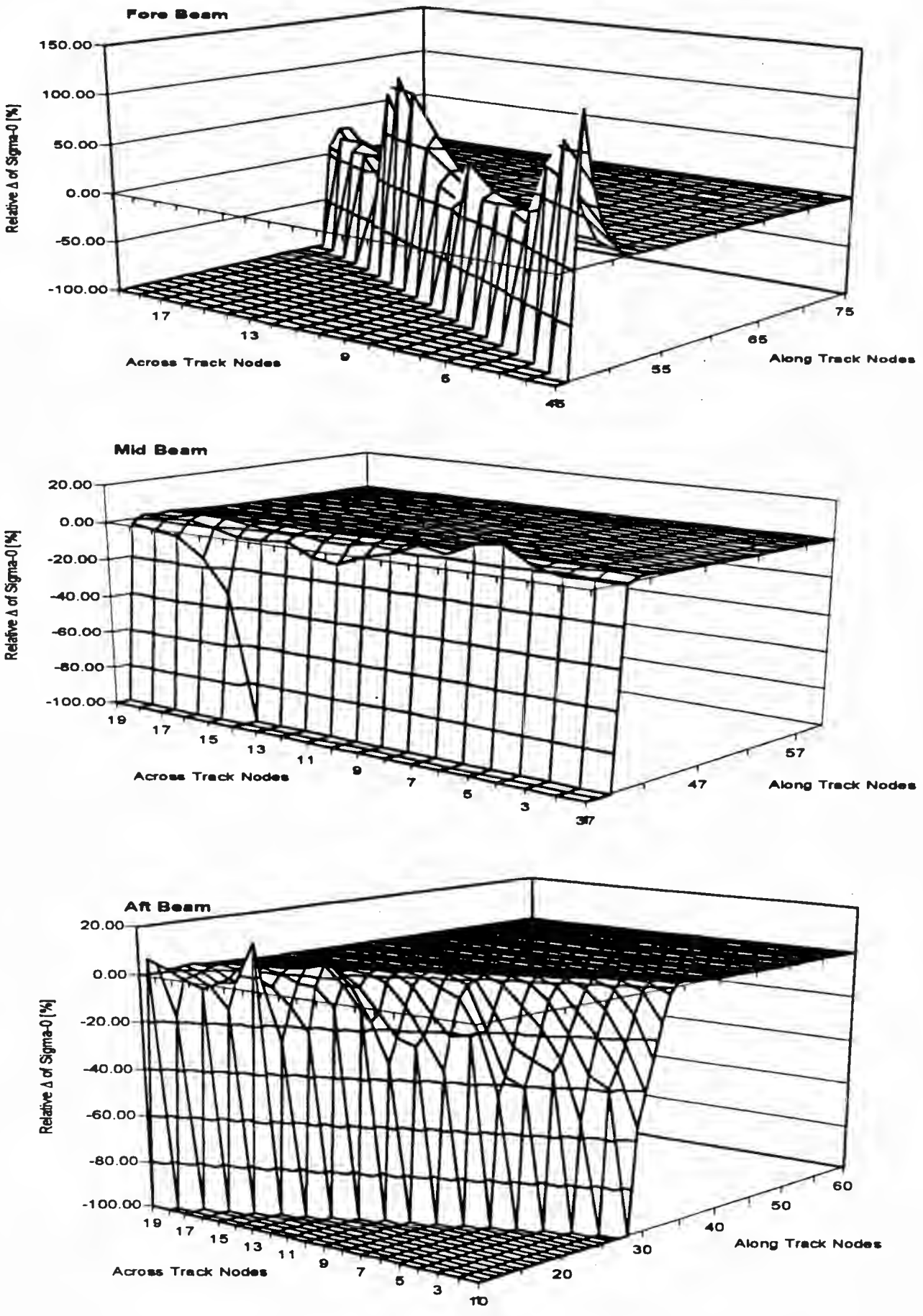


Figure F6: Relative Difference of Sigma-0 Products (Instrument Switch-on vs. Wind Mode Sequence)

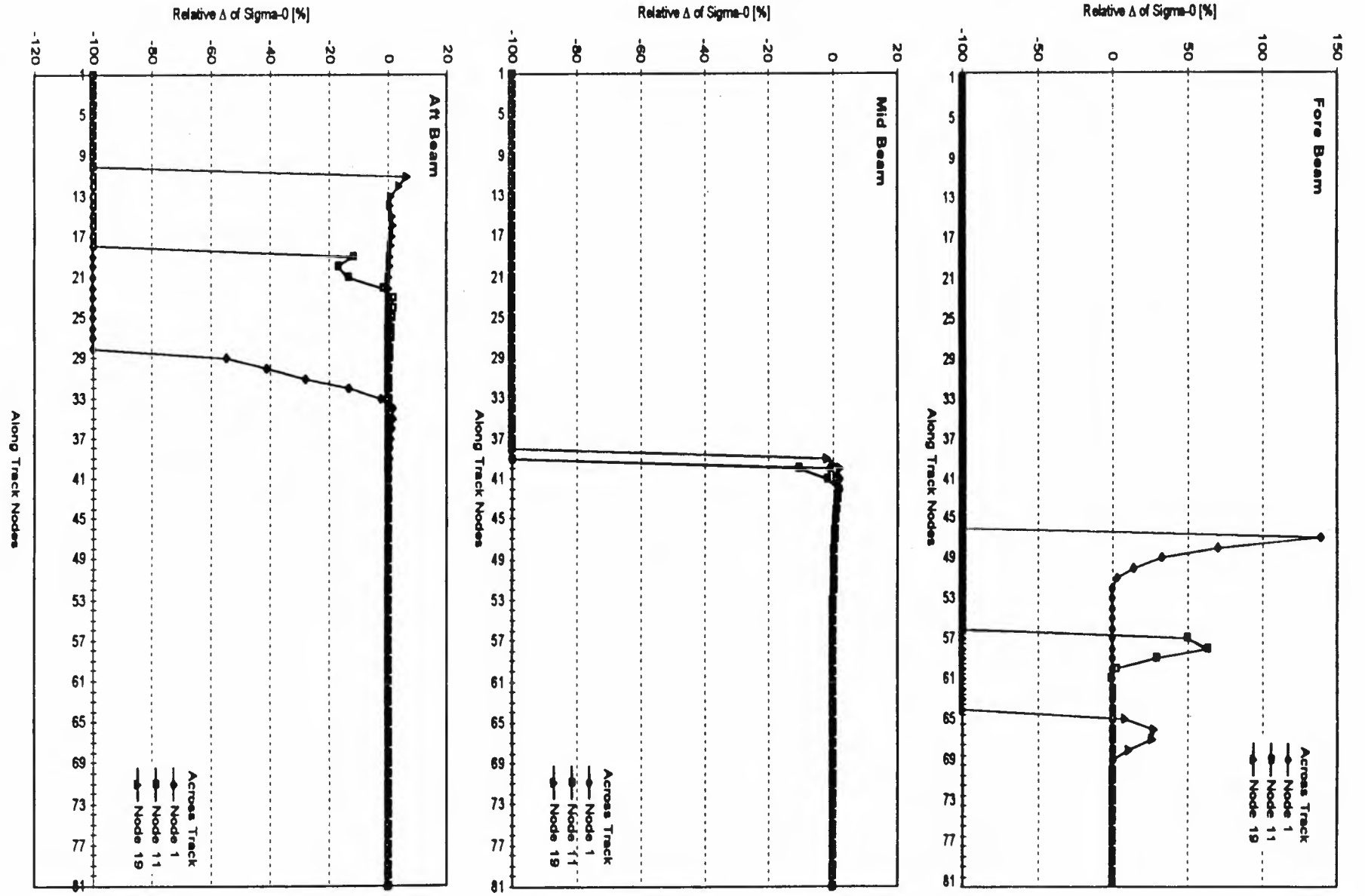


Figure F7: Deviation of Switch-on Mode Product for Across Track Nodes 1, 11 and 19

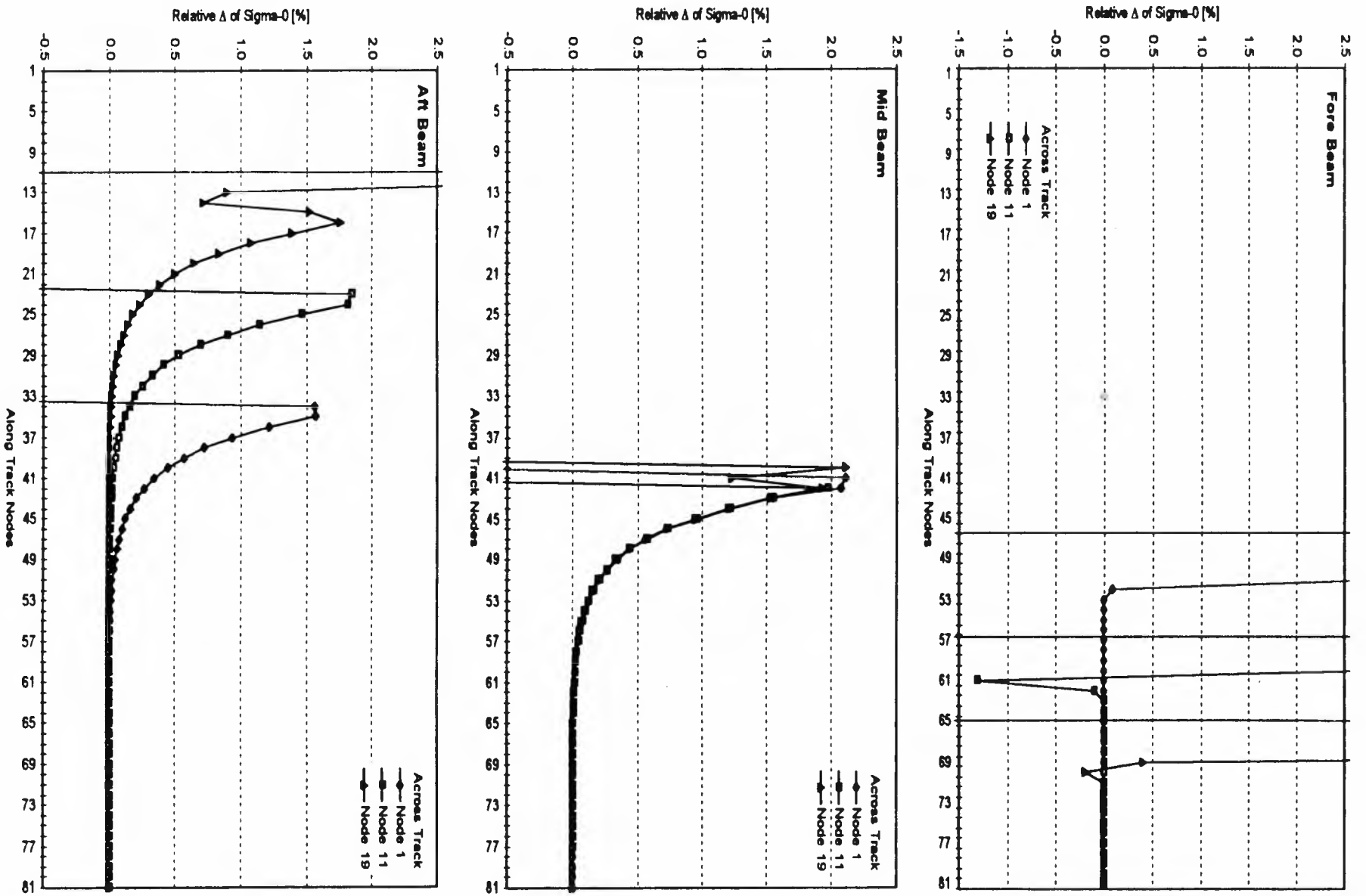


Figure F8: Deviation of Switch-on Mode Product for Across Track Nodes 1, 11 and 19
(Zoomed for Relative Deltas between -0.5% and 2.5%)

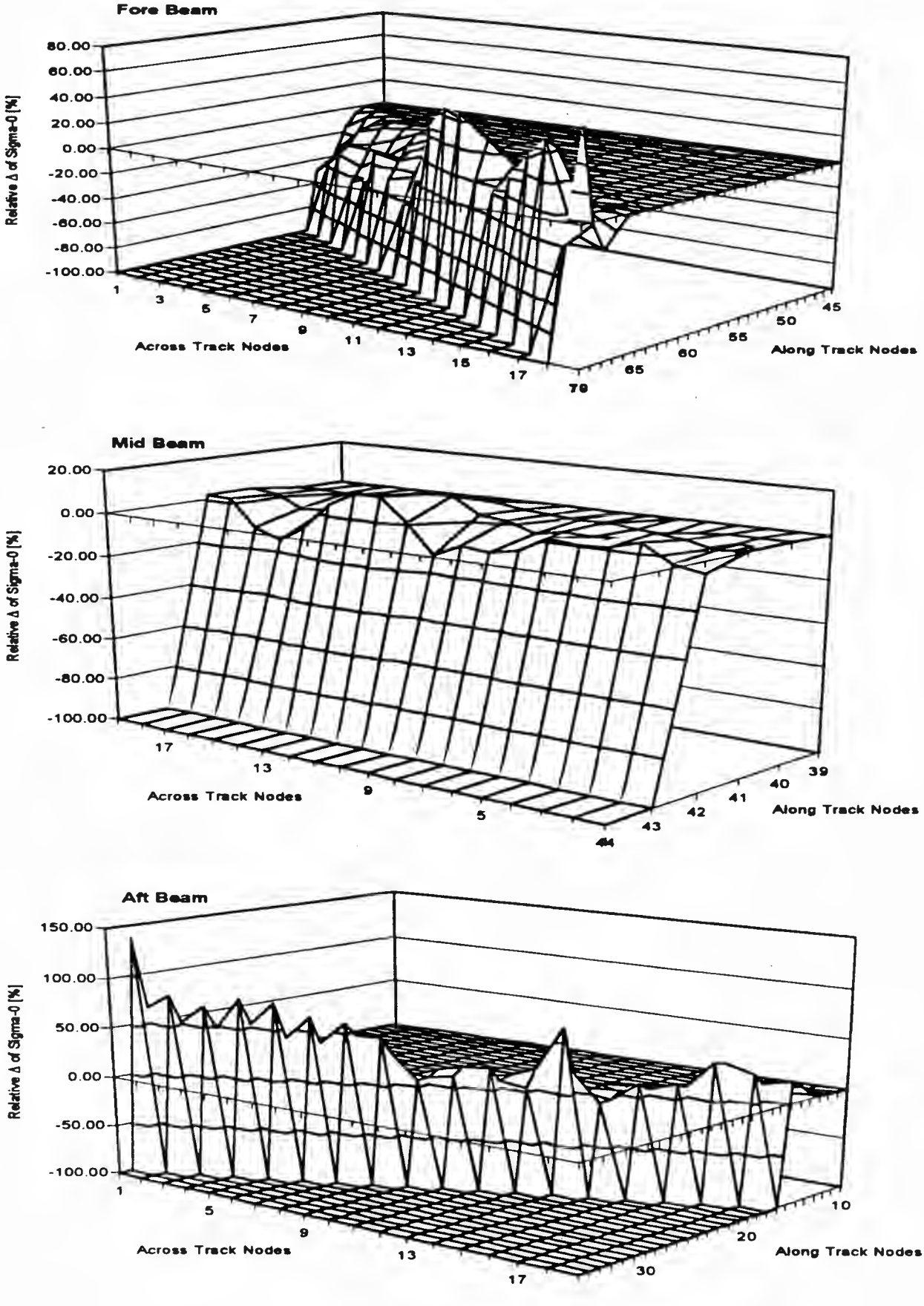


Figure F9: Relative Difference of Sigma-0 Products (Instrument Switch-off vs. Wind Mode Sequence

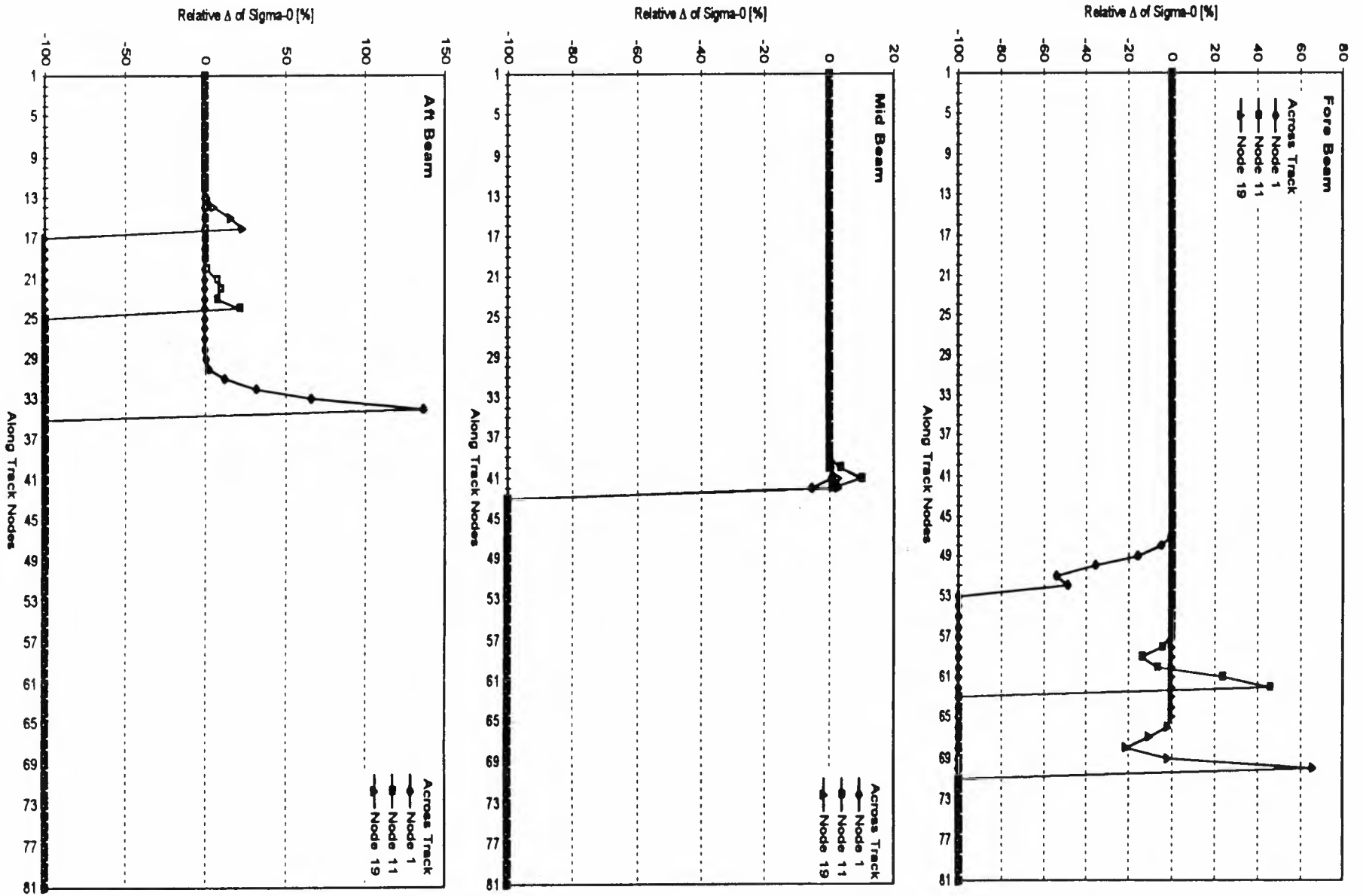


Figure F10: Deviation of Switch-off Mode Product for Across Track Nodes 1, 11 and 19

4. Analysis of Effect on the Complete Ground Processing (5) - Scene 2

Undisturbed case shows

- incidence angle dependent drop of σ^0 across track
- rather smooth variation along track

Disturbed cases show in summary the same effects as for scene 1

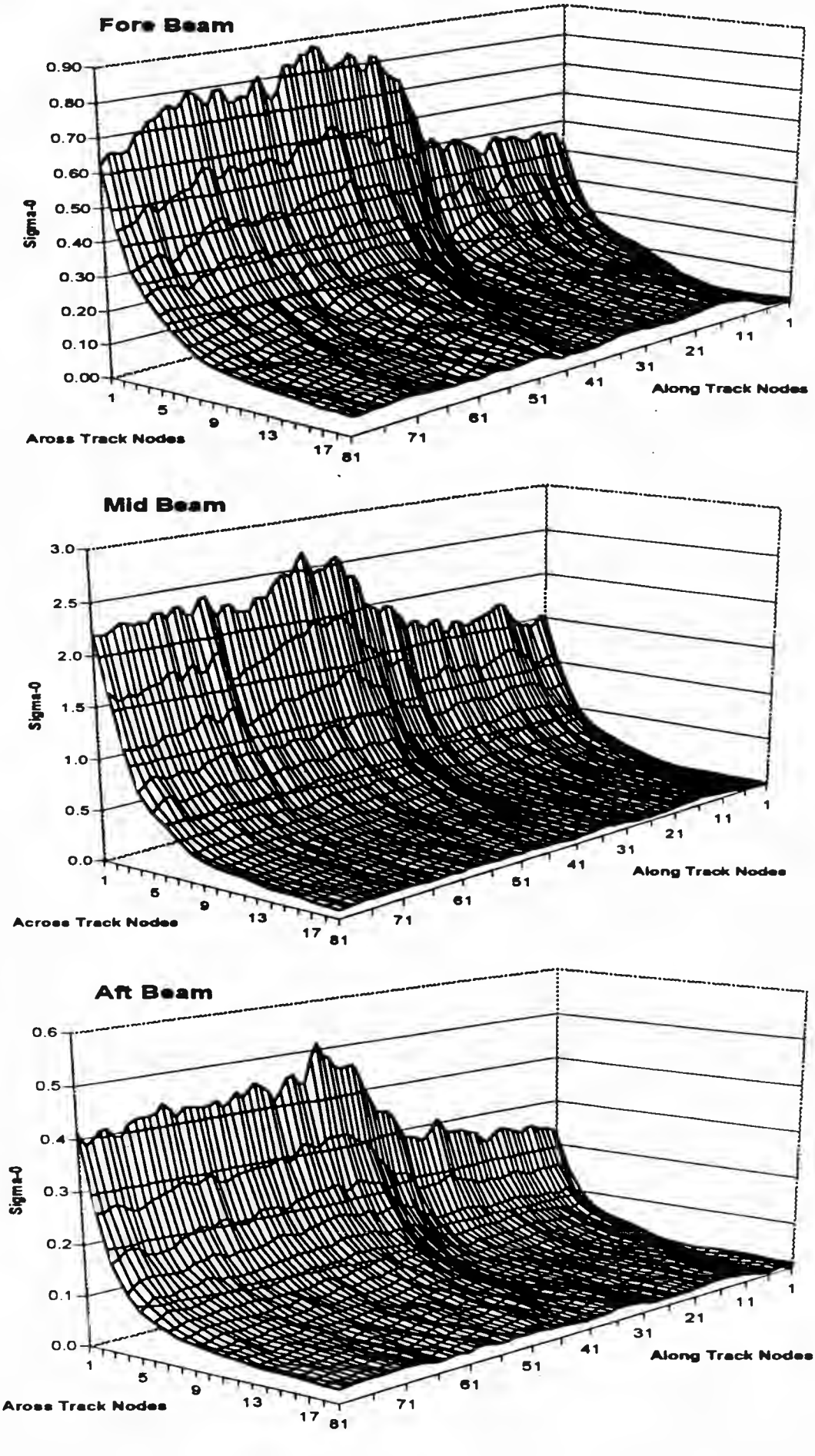


Figure G1: Undisturbed Sigma-0 Product for Scene 2

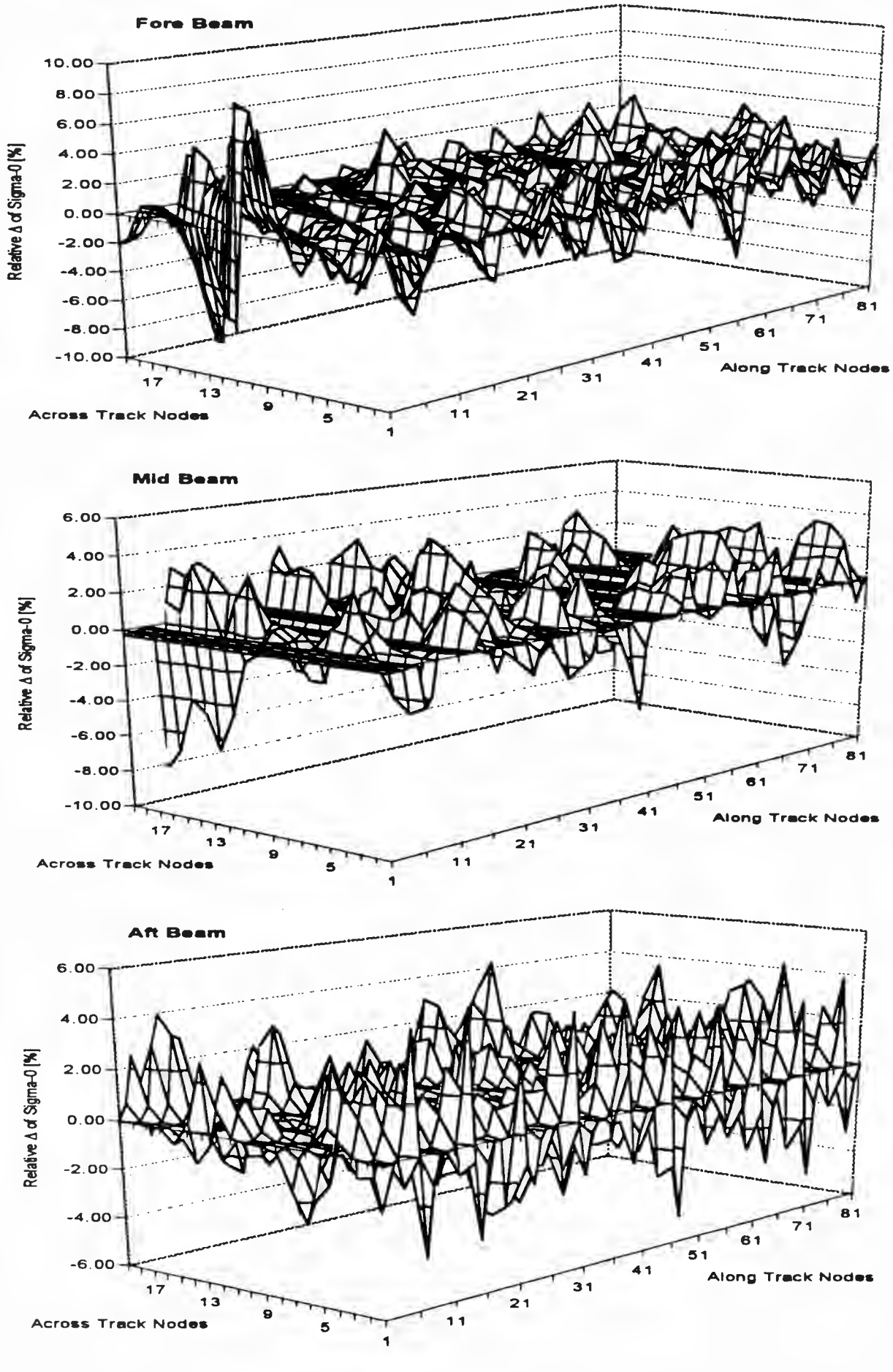


Figure G2: Relative Difference of Sigma-0 Products (Wind Wave Mode vs. Wind Mode Sequenc

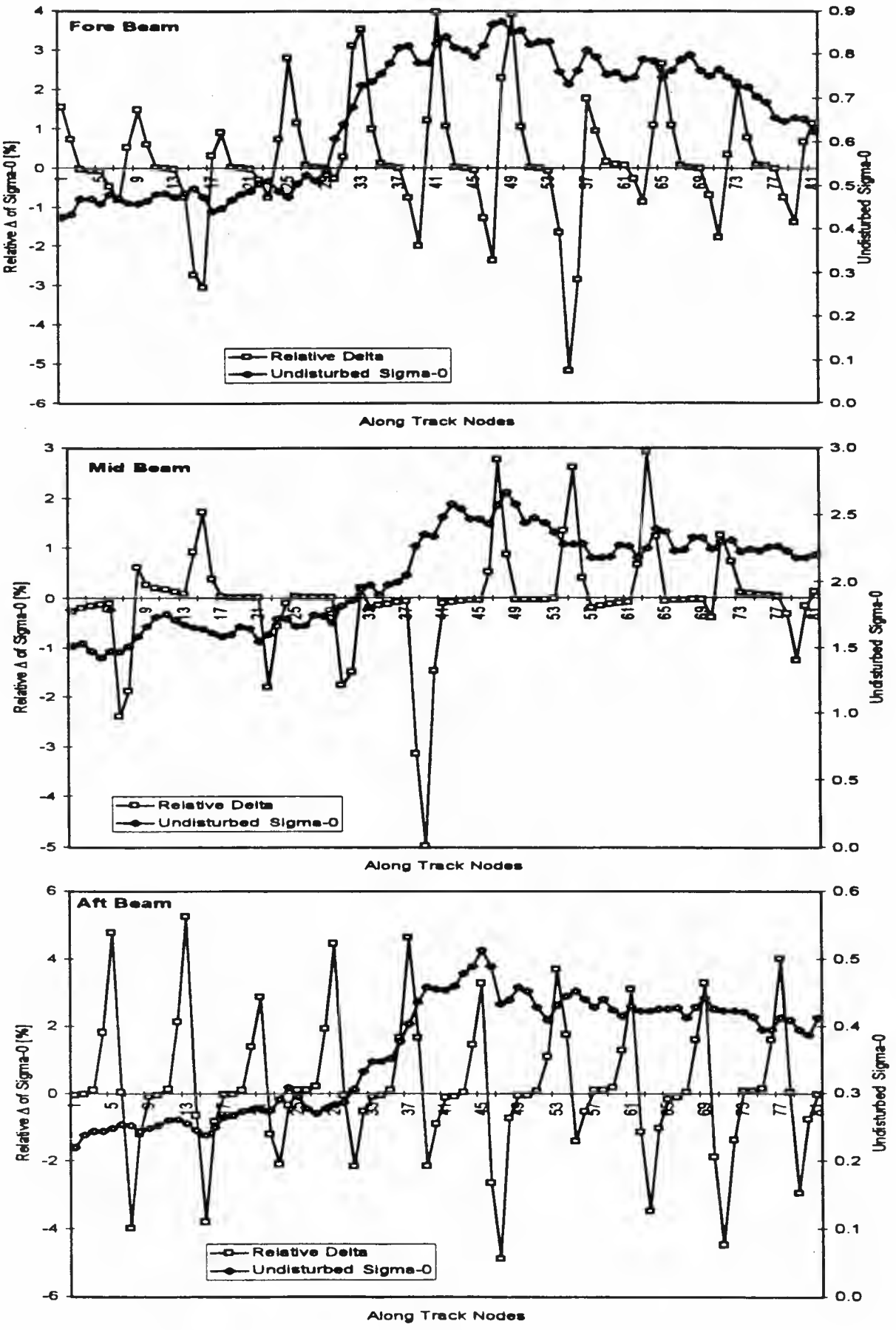


Figure G3: Deviation of Wind//Wave Mode Product for Across Track Node 1

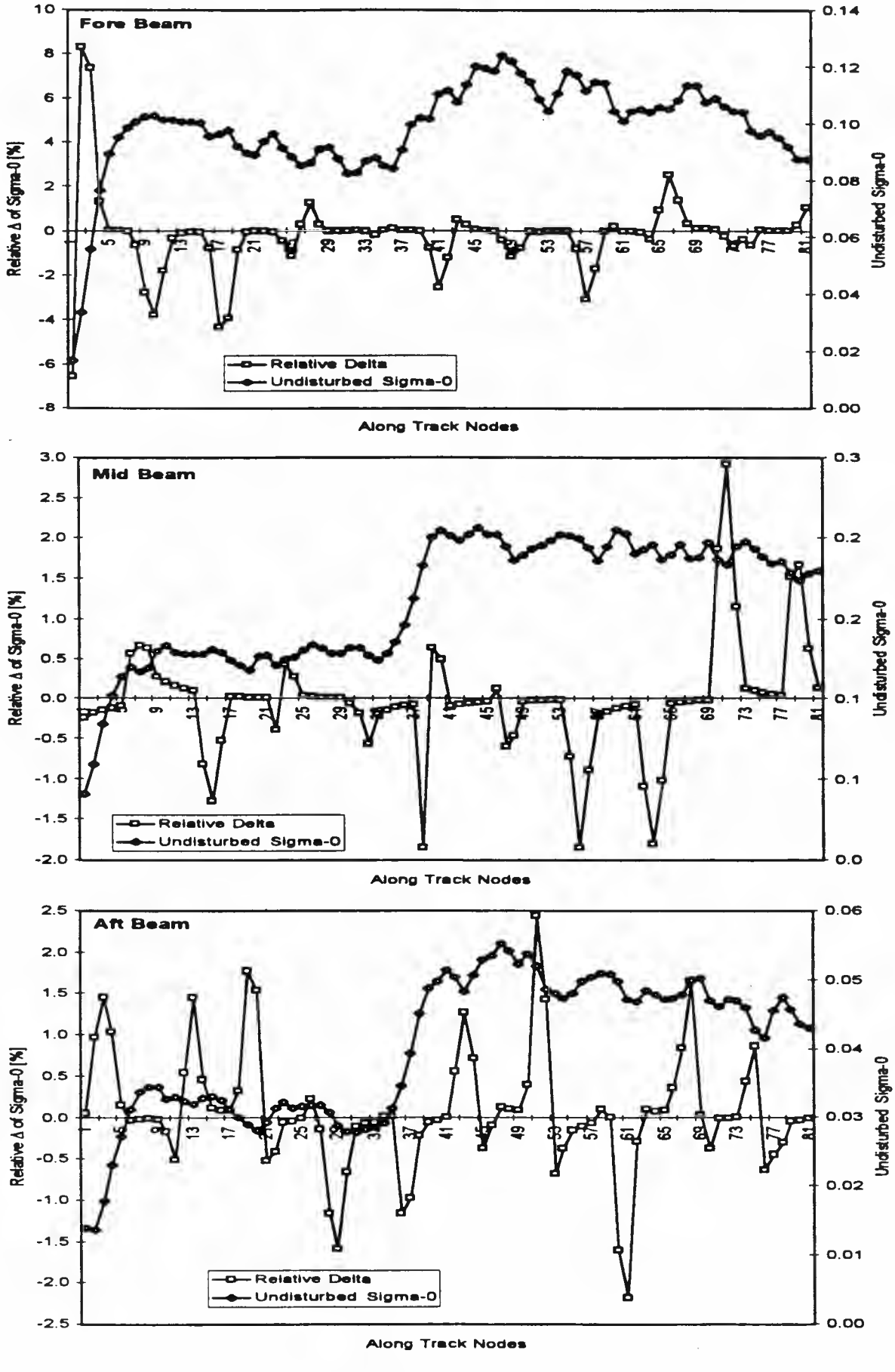


Figure G4: Deviation of Wind//Wave Mode Product for Across Track Node 11

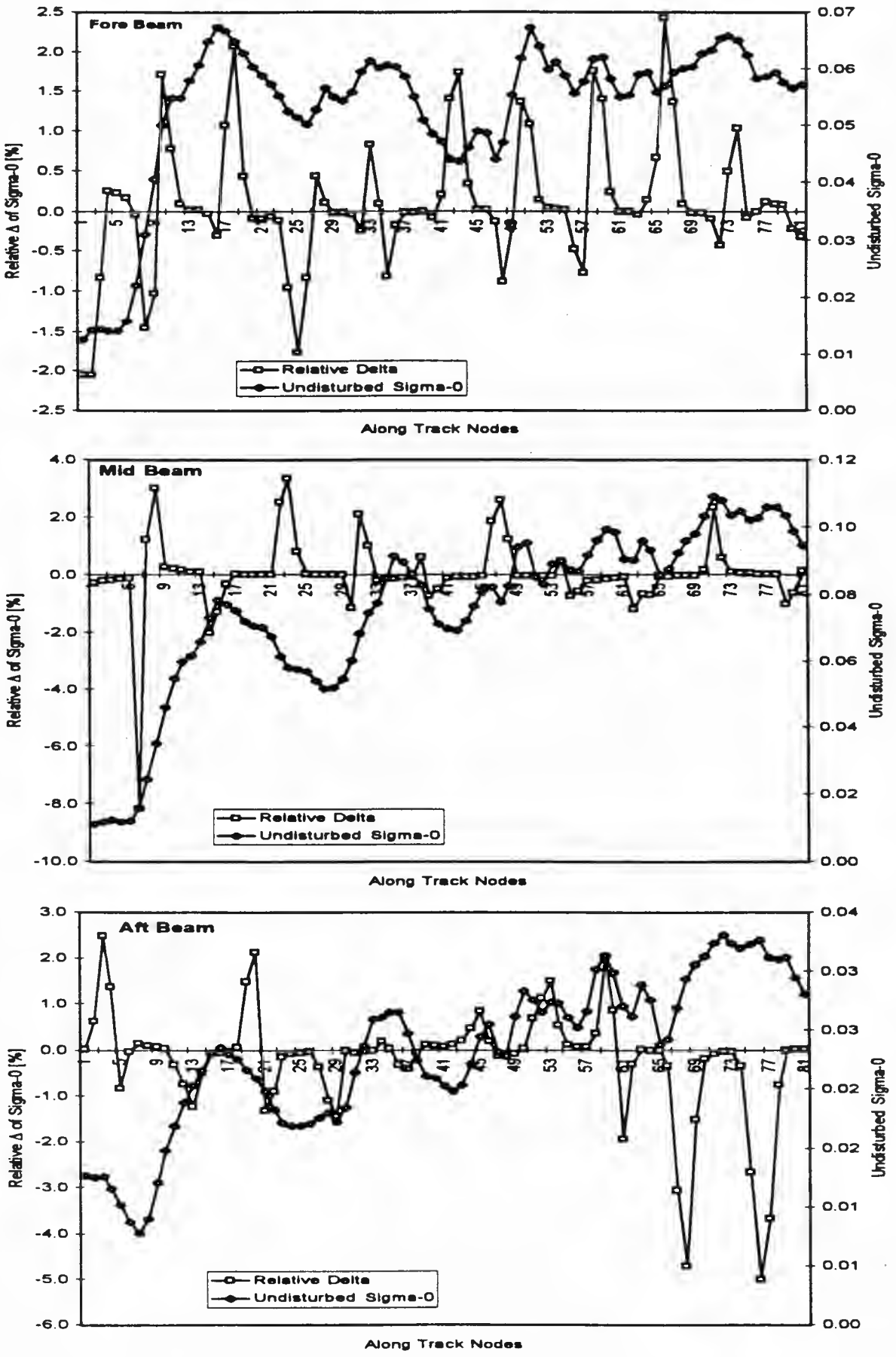


Figure G5: Deviation of Wind//Wave Mode Product for Across Track Node 19

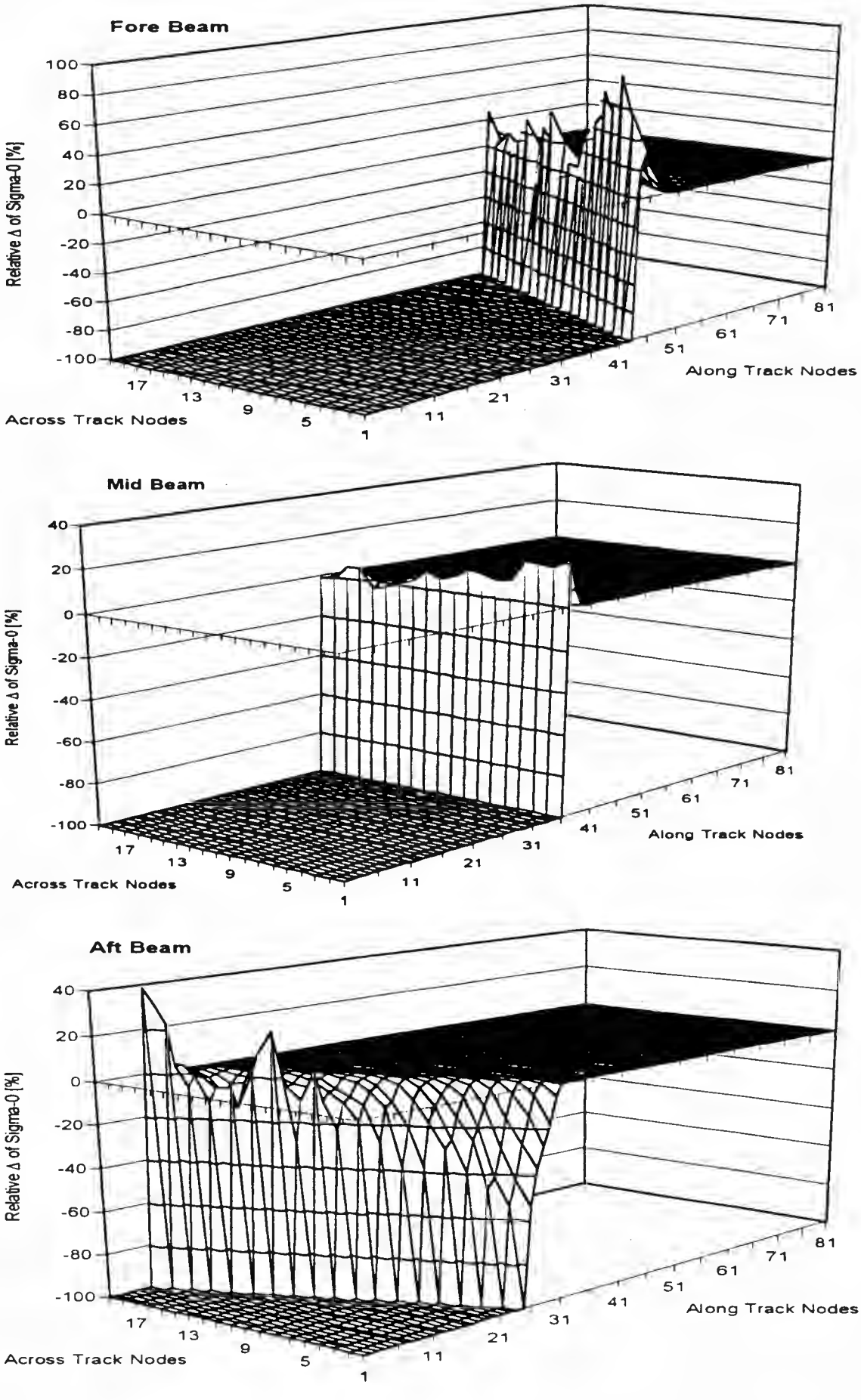


Figure G6: Relative Difference of Sigma-0 Products (Instrument Switch-on vs. Wind Mode Seque

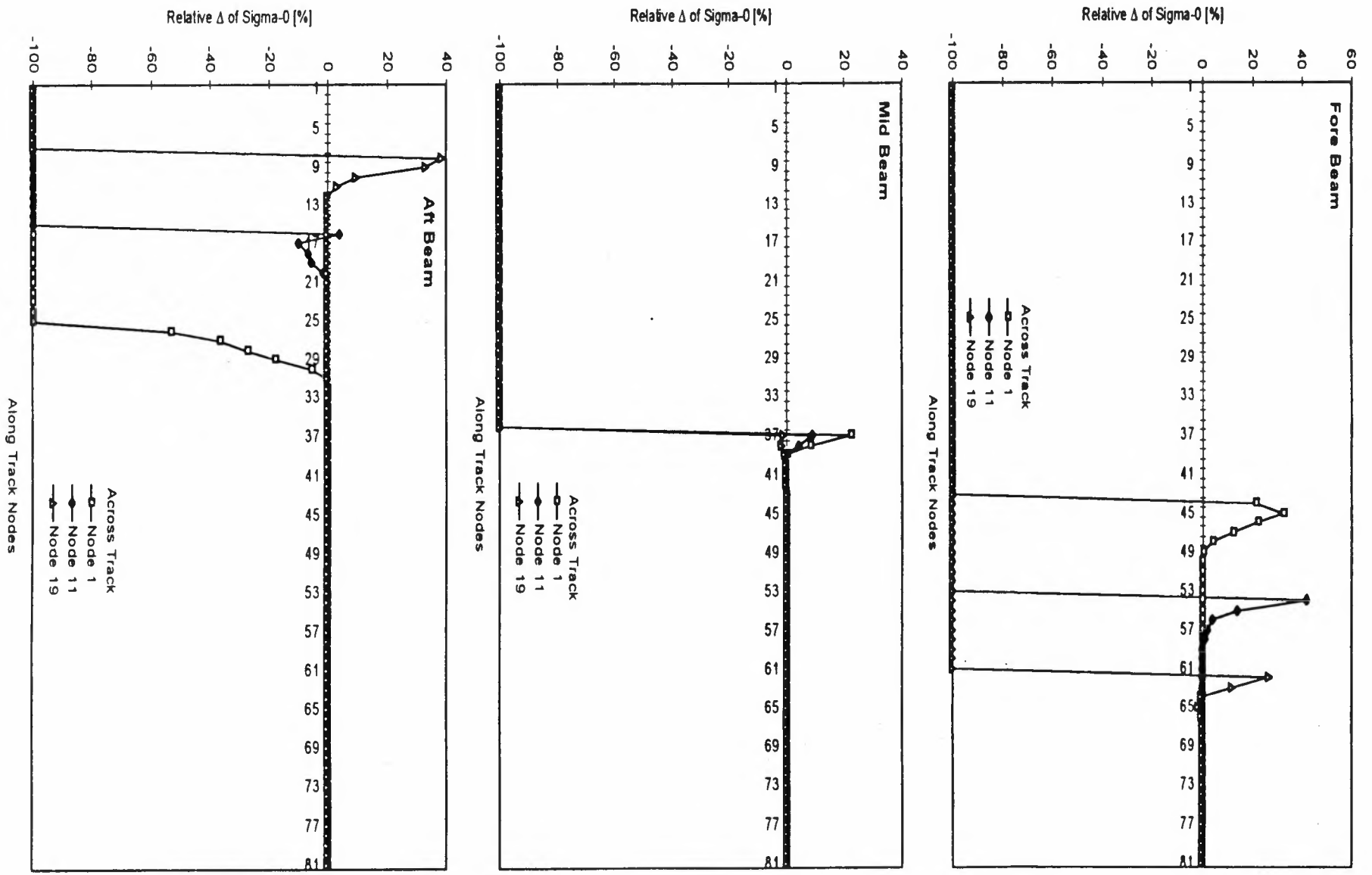


Figure G7: Deviation of Switch-on Mode Products for Across Track Nodes 1, 11 and 19)

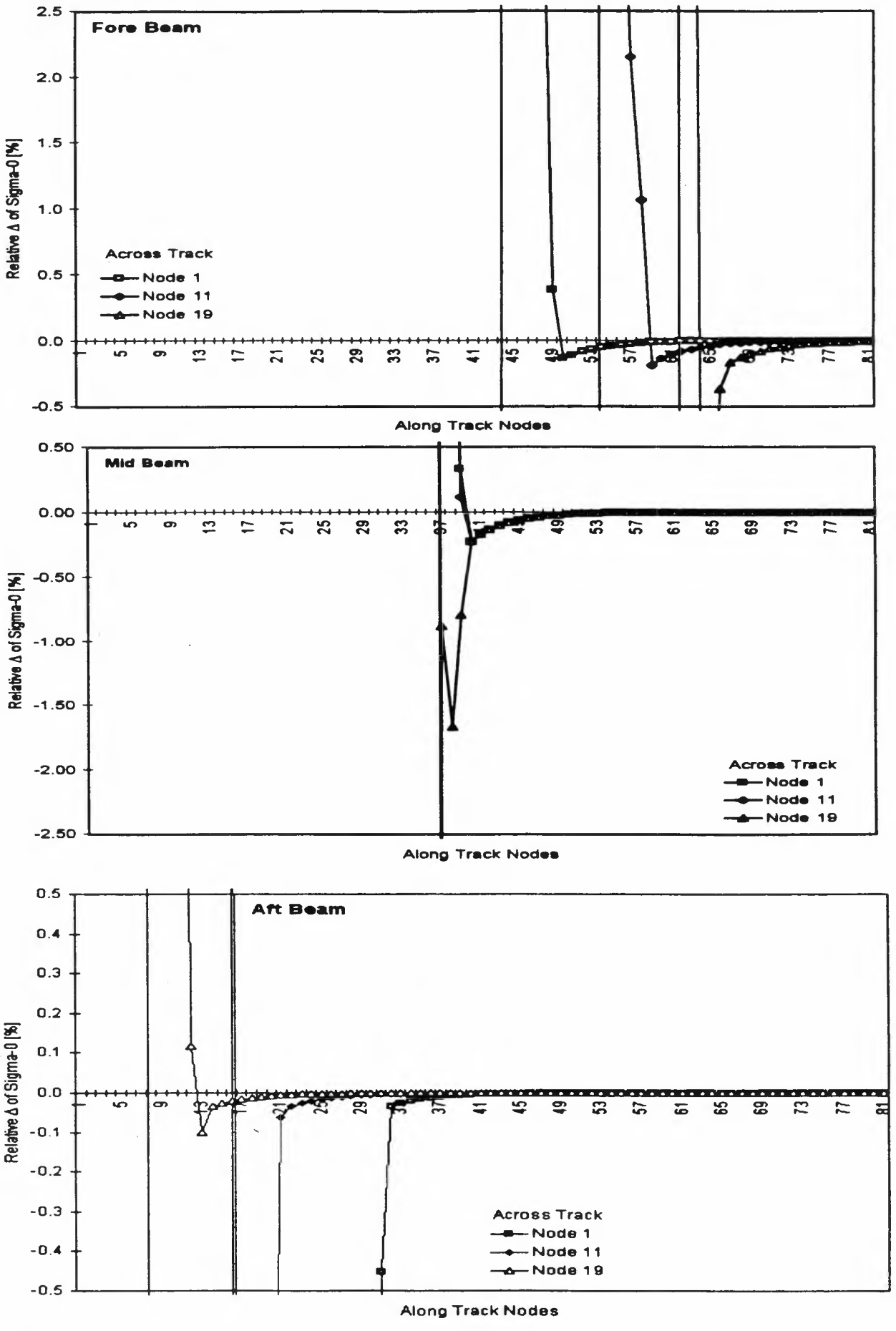


Figure G8: Deviation of Switch-on Mode Products for Across Track Nodes 1, 11 and 19)
(Zoomed for Relative Deltas between -2.5% and 2.5%)

5. Conclusions (1)

The following effects have been observed (case 1 = wind/wave mode, 2/3 = switch on/off):

a) offset in the expected σ^0-value due to missing echo samples for high/low incidence angles antennas affected: fore/aft
size of effect: maximum from 5% (near range) to 0.4% (far range) for case 1)
maximum from 150% (near range) to 12% (far range) for cases 2+3)

b) increase in the kp-value due to reduced number of samples in the spatial averaging
size of effect: maximum 7.5% (fore/aft) , 12% (mid) for case 1)
maximum 800% (fore/aft) to 400% (mid) for cases 2+3)

c) offset in the calculated σ^0-value due to missing echo samples if the wind conditions and derived σ^0 - values are varying across the spatial filter area
size of effect: depending on variation of wind condition, several percent (case 1) to several tens of percent (cases 2+3)

5. Conclusions (2)

The following effects have been observed (cont'd):

d) variation in the calculated σ^0-value due to the fact, that the statistical averaging is done over a different (but correlated) sample set
size of effect: less than the expected kp - value

e) variation in the calculated calibration correction factor due to the fact that the averaging of the derived calibration pulse power is done over a different set of samples
size of effect: less than 0.5% for ERS-1 gain settings (case 1)
not quantifiable as masked by effect f) (cases 2+3)

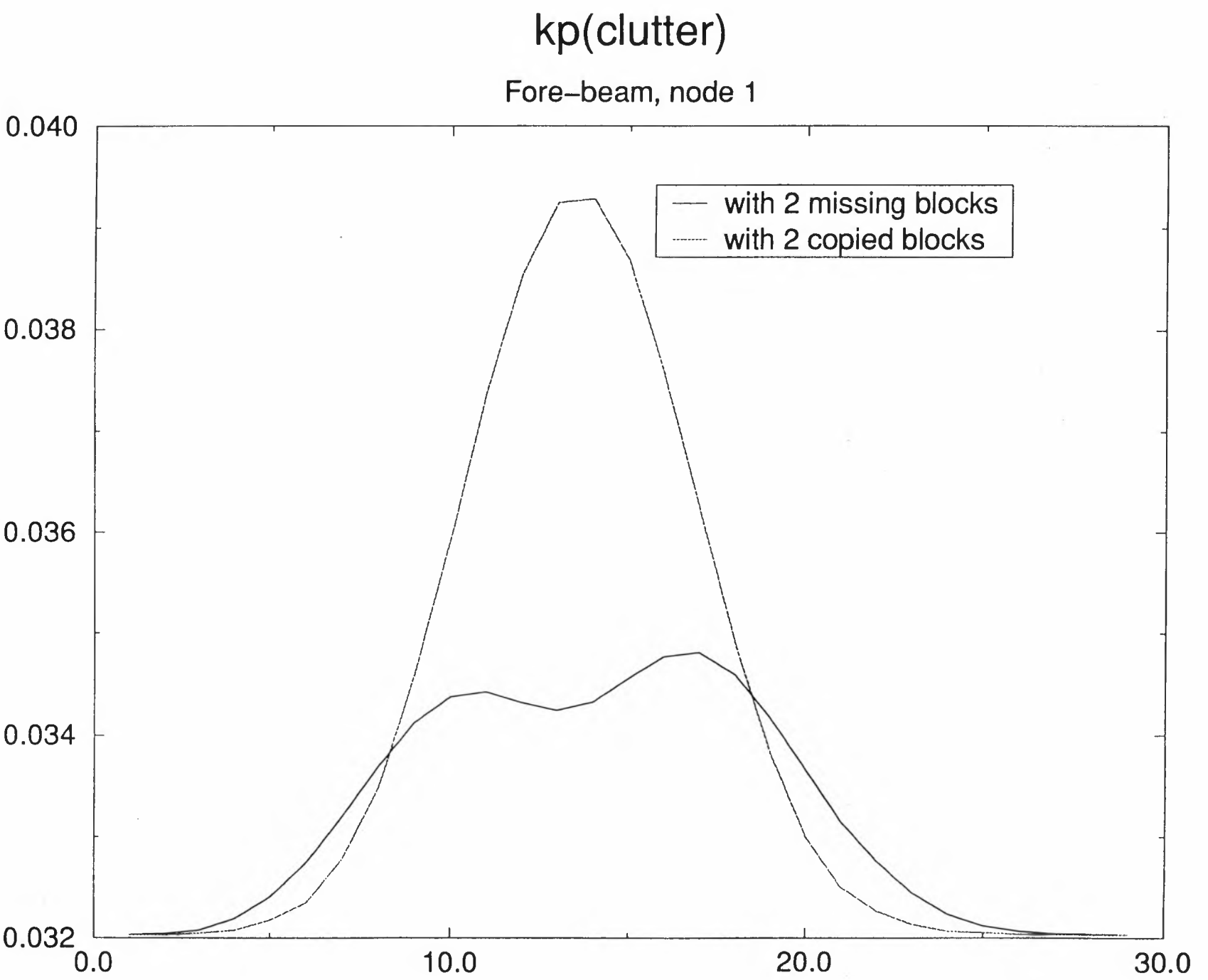
f) offset in the calculated calibration correction factor due to start of calibration pulse filter (only for case 2)
size of effect: depends on the calibration filter initialisation. Size observed: 1.8%.

5. Conclusions (3)

Possible modifications to improve of ground processing in case of missing source packets:

A1) Generation of auxiliary echo data to substitute the missing ones by copying suitable neighbouring echo samples.
- approach only suitable for cases, where only a few source packets are missing (e.g. wind/wave gaps), as otherwise no efficient averaging of samples is obtained (high resultant kp).
- in cases of a few missing source packets, the resultant kp may decrease with respect to the case of gaps in the echo data (it always increases with respect to the undisturbed case), if samples with a low weighting factor are copied and increase, if the copied samples are associated with high spatial filter weights. The effect on the point target response needs to be analyzed.

This approach will also reduce the deviation for situation c), if the trend in wind condition change is maintained over several source packets and the copying is done symmetrically with respect to the gap.


kp(clutter)
Fore–beam, node 1
0.040
0.038
0.036
0.034
0.032
0.0
10.0
20.0
30.0
with 2 missing blocks
with 2 copied blocks

5. Conclusions (4)

A2) Correct the incidence angle used in the wind extraction process by the shift in centre of gravity of the incidence angle caused by the missing echo samples.
- This approach has no side effect on any of the situations b) through f).
- As σ^0 is not a linear function of the incidence angle (for constant wind), this correction does not remove the impact on the extracted wind completely. A first estimate indicates that the correction is equivalent to a reduction of the deviation in σ^0 by 75%.

B1) Calculate speckle part of Kp on-line by considering the spatial filtering process as a weighted averaging process.
- the residual speckle is estimated as the standard deviation of this averaging process.
- the echoes of each pulse are correlated over the pulse length (this has to be taken into account in addition to the weighting).
- an estimation of the correlation coefficient on purely geometrical terms is not very difficult . In reality, there is also some additional decorrelation due to the residual change in Doppler (depending on swath and orbit position) and the quantization noise (depending on the echo level in the I - and Q - channels.

5. Conclusions (5)

Correctability of effects observed by the above methods

Method / Effect	a)	b)	c)	d)	e)	f)
A1	x	(x)	(x)			
A2	x					
B1		(x)*				

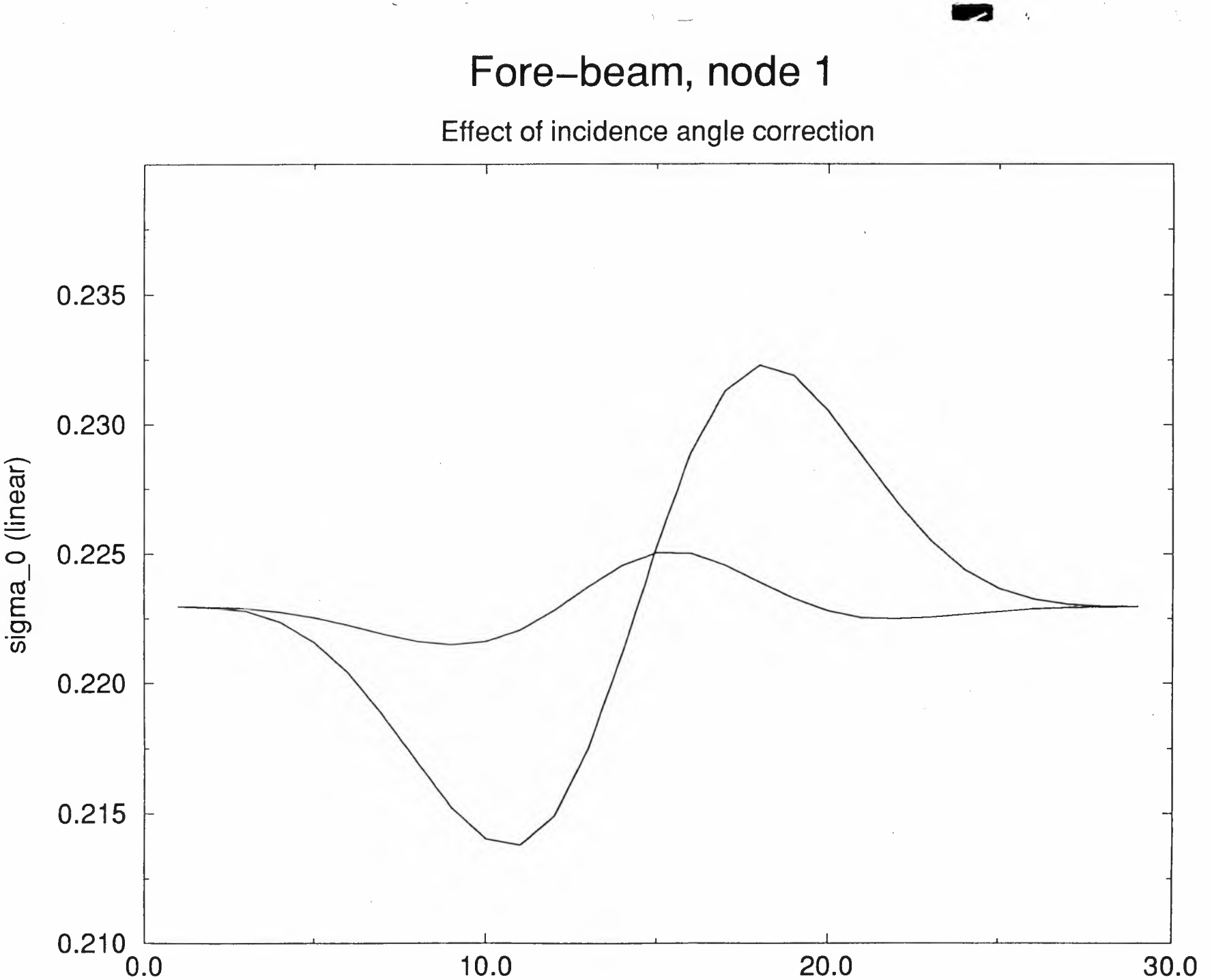
* Improvement of knowledge of kp, not reduction of value

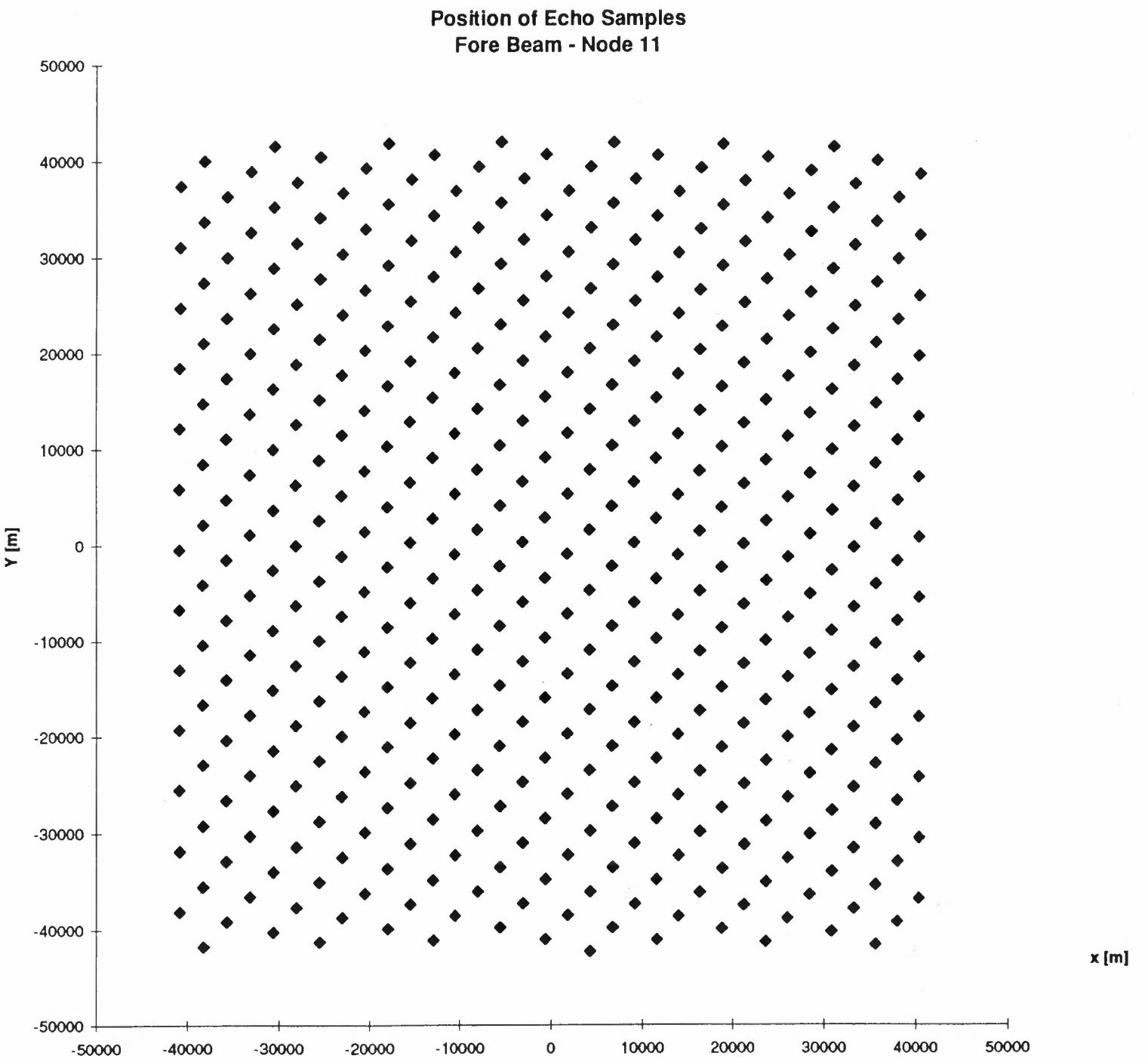
5. Conclusions (6)

In summary, the following further proceeding seems appropriate:

- The methods A1 and A2 are further investigated for the wind/wave mode and the instrument switch on/off cases if only a few source packets are missing. For these cases the change in kp - value due to the missing source packets is rather small (see section 4.5). As method B1 implies rather big changes to the existing scatterometer processing algorithms, it should be carefully analyzed whether method B1 should be pursuit any further, depending on the sensitivity of the wind extraction algorithm on the accuracy of the kp - estimate.

- If more than a few source packets are missing at instrument switch-on/off, the relevant nodes are neglected in the windextraction step.


Fore–beam, node 1
Effect of incidence angle correction
sigma_0 (linear)
0.235
0.230
0.225
0.220
0.215
0.210
0.0
10.0
20.0
30.0


Position of Echo Samples
Fore Beam - Node 11
Y [m]
x [m]
50000
40000
30000
20000
10000
0
-10000
-20000
-30000
-40000
-50000
-50000
-40000
-30000
-20000
-10000
0
10000
20000
30000
40000
50000