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LARGE-ARRAY SIGNAL AND NOISE ANALYSIS
Special Scientific Report No. 15
TRAVELTIME ANALYSIS FOR LASA

Prepared by
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Science Services Division
P.O. Box 5621
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Contract No. AF 33(657)-16678

Prepared for
AIR FORCE TECHNICAL APPLICATIONS CENTER
Washington, D.C. 20333

Sponsored by
ADVANCED RESEARCH PROJECTS AGENCY
ARPA Order No. 599
AFTAC Project No. VT/6707

20 December 1967

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SECTION I

INTRODUCTION AND SUMMARY

This special report investigates several practical aspects of generating high-resolution wavenumber spectra using subarray outputs of the Montana LASA. The following are questions of particular interest:

- Variability of traveltimes anomalies as a function of wavenumber
- Spectral window effect on crosspower estimates due to moveout across the array
- Tradeoffs involved in a finite length transform of array data

These questions are investigated with either easily available data or simple models of the situation being considered. A general understanding of the type of constraints encountered, rather than an exact mathematical treatment of each situation, is desired.

A. TRAVELTIME ANOMALY VARIATIONS

Variations in traveltimes anomalies were analyzed using punched cards obtained from the Seismic Data Laboratory, Alexandria, Virginia. The punched cards contained the date, time, latitude, longitude, and arrival time recorded at each LASA subarray for 384 teleseismic events.

A map of the world, as seen teleseismically (in \vec{k} -space) from LASA, was overlaid with a grid containing 58 divisions in the north-south direction and 48 divisions in the east-west direction. The edges of the grid were tangent to the circle corresponding to a 10-km/sec velocity across LASA. Each of the 384 events was assigned to the block on the grid containing its epicenter. The average traveltimes residual (anomaly) for each subarray was computed for each block containing one or more events.



Several adjacent blocks were compared using the mean residual computed for each subarray. The following general characteristics were observed in this traveltime anomaly analysis:

- Variations in traveltime residuals for adjacent blocks were of the order of the standard deviation of the data in each block
- Variations between blocks in a 3- to 5-block region were greatest for events coming from South America
- Only 113 blocks contained events; of these, only 25 had five or more events
- Subarrays on the E and F rings generally had larger means and standard deviations in their residuals than did the inner subarrays

From these observations, the data appeared to be insufficient to define residual correction functions covering the wavenumber regions of interest. Until sufficient data are available to define such functions with reasonable confidence, no generalized attempt will be made to correct the wavenumber spectra calculations for traveltime anomalies.

B. MOVEOUT WINDOW ANALYSIS

A simple single-frequency plane-wave model was used to analyze the spectral window due to a "boxcar" smoothing function applied to a crosspower spectra. When a crosspower spectrum is formed from two finite time series, some type of smoothing is always present. The spectral window resulting from crosspower smoothing is a function of both the time-series length (T) and the signal moveout (τ_{ij} , the signal traveltime from the i^{th} to the j^{th} sensor). The spectral window function for this case is

$$H(\Delta f, \tau_{ij}) = \frac{\sin(\pi \Delta f \tau_{ij})}{(\pi \Delta f \tau_{ij})}$$



where Δf is the width of the "boxcar" smoothing function. The smallest Δf (least smoothing) obtainable with a time series of length T is

$$\Delta f = \frac{1}{T}$$

This results in the following relationship between data length T , the moveout between channels τ_{ij} , and the magnitude of the crosspower estimate $\hat{\tau}_{ij}$:

$$\hat{\tau}_{ij} = \frac{\sin\left(\pi \frac{\tau_{ij}}{T}\right)}{\left(\pi \frac{\tau_{ij}}{T}\right)} \tau_{ij}^T$$

where τ_{ij}^T is the true crosspower between channels i and j . The crosspower estimate will then have a magnitude of 90 percent of the true crosspower magnitude when the ratio $\frac{\tau_{ij}}{T} \leq 0.25$.

Transform gate lengths should be about four times the largest expected moveout across the array if crosspower estimates between channels are to be meaningful.

The importance of this criterion is apparent when more than one signal is present. In the case of two plane wavefronts of different apparent velocity, the phase of the crosspower spectrum has an ambiguous interpretation. This ambiguity can be resolved if the crosspower magnitude estimates between pairs of sensors are close to the true crosspower magnitudes.

Currently, the effect on f - \vec{k} spectra of normalizing the crosspower estimates in a multiple-signal environment is not fully understood; this aspect of computing high-resolution f - \vec{k} spectra is the object of further investigation.



C. TRADEOFF IN FINITE-LENGTH TRANSFORMS OF ARRAY DATA

As the aperture of a seismic array increases, the data transform gate must be correspondingly increased to keep the spectral window from deteriorating the information. This increase in transform gate reduces the effective signal-to-noise ratio when the signals of interest are transients within the gate. This decrease in signal-to-noise ratio can be offset by adding more sensors as the aperture is increased, assuming that signals of the same minimum apparent velocity are applicable to both arrays. Change in signal-to-noise ratio due to change in array diameter from d_k to d_l and change in number of sensors from N_k to N_l can be expressed as

$$H_{l, k} = \left(\frac{d_k}{d_l} \right) \left(\frac{N_l}{N_k} \right)$$

This formula indicates that doubling the number of sensors and doubling the aperture will not change the signal-to-noise improvement expected in frequency wavenumber spectra calculations. At LASA, the E and F rings successively double the aperture of the previous array but add only four sensors each. The available signal-to-noise improvement is then decreased when these two outer rings are included in frequency-wavenumber spectra calculations.

D. SUMMARY

From this section, it is concluded that current data are insufficient to adequately describe the amplitude, traveltime, and waveform anomalies at LASA. Additionally, subarrays on the E and F rings will not be used in frequency-wavenumber spectra evaluation. These subarrays will be used for teleseismic event detection using the current LASA detection scheme.



SECTION II

COMPARISON OF TRAVELTIME RESIDUALS

The assumption of space stationarity necessary for computing meaningful wavenumber spectra may not prove to be a valid assumption for large-diameter arrays such as LASA. Departures from the assumed plane wavefront of constant waveform moving at constant velocity may be due to two primary factors: the first is instrument response variations and should be independent of wavenumber; the second is the effect introduced by different ray paths and different seismometer-to-earth couplings. Upper mantle inhomogenities, due to variations in thickness and composition, will probably be a function of wavenumber (Appendix B).

At least part of the second factor can be determined empirically by computing the residuals caused by the difference between theoretical and actual arrival times at each subarray for a teleseismic P-wave from an event of known epicenter. These computed time residuals yield the phase corrections used when computing the portion of a wavenumber spectra corresponding to that epicentral location. In this report, there is no attempt to analyze amplitude anomalies at LASA.

A. WAVENUMBER GRID FOR LASA

Standard wavenumber spectra computed by Texas Instruments Incorporated are printed out on an alphabetically coded grid. This produces a square area on an IBM-computer printed page. Consistent with this format, a map of the world as seen teleseismically from LASA was overlaid with a 58-row by 48-column grid. Rows were aligned in the east-west direction. The grid's edges were tangent to the circle representing the loci of epicenters which would theoretically produce a 10-km/sec signal velocity across LASA. Figure II-1 shows the wavenumber grid for LASA.

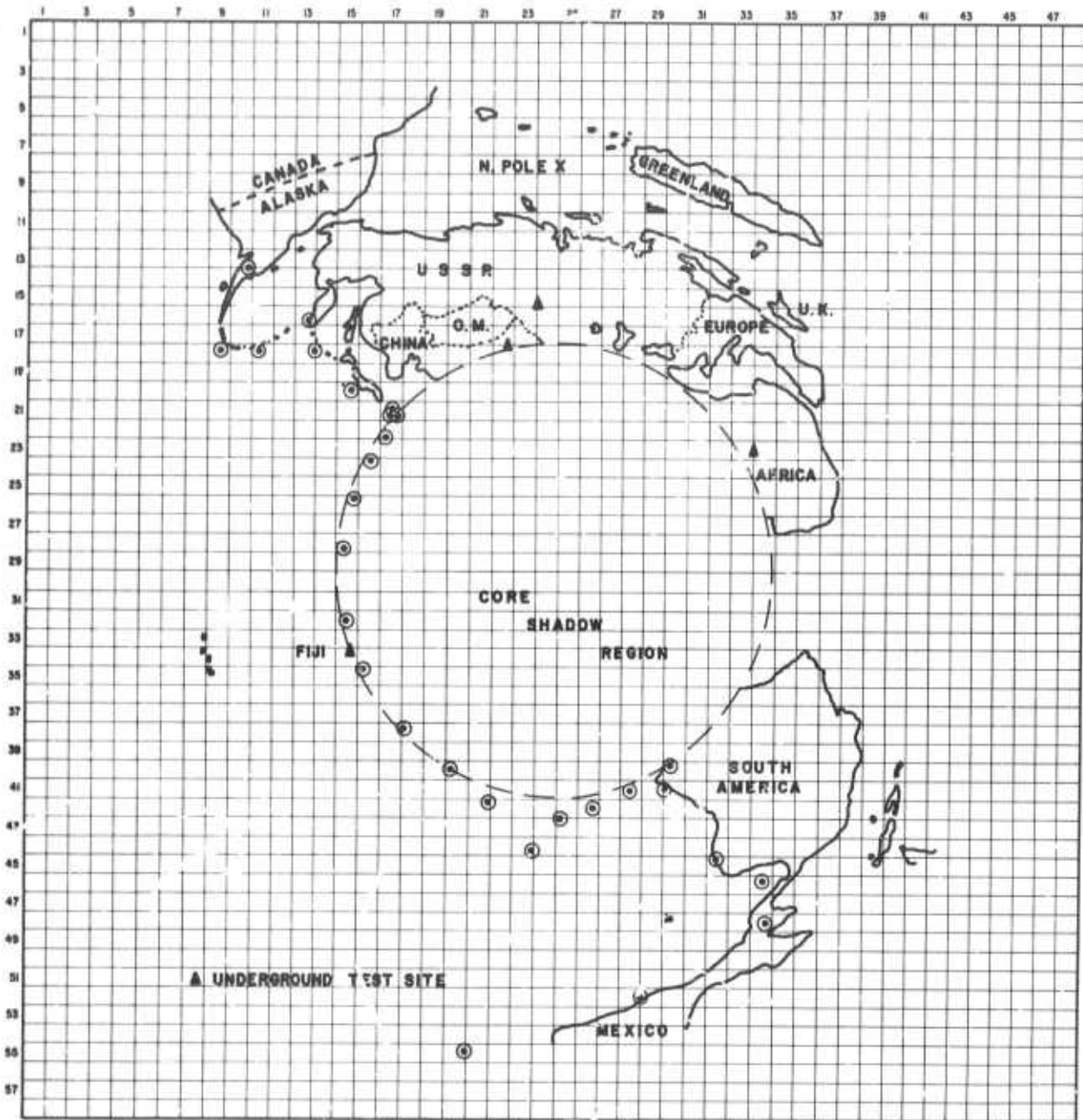


Figure II-1. Wavenumber Grid for LASA



B. LASA TRAVELTIME ANOMALY COMPUTATIONS FOR BLOCKS OF WAVENUMBER SPACE

The wavenumber plane is divided into a grid of equal-sized blocks to correct for traveltime anomalies when computing frequency-wavenumber spectra from LASA data. Since different blocks of the same size in wavenumber space cover different sizes of epicentral area, a special computation is needed to determine the anomalies for a particular block from the available anomaly information.

The TI standard wavenumber printout is on an alphabetically coded grid; the wavenumber plane is divided into 58 blocks in a north-south direction (k_y) and into 48 blocks in the east-west direction (k_x). The edges of the grid are tangent to a minimum-velocity circle of 10 km/sec. A particular block in the grid is always associated with the same area on the surface of the earth as seen from the Montana LASA.

The data used in the tabulation include 384 events with date, latitude, longitude, and arrival time (hours, minutes, and seconds) for each subarray on punched cards. A program has been written to read the data and perform the following calculations.

- Epicentral angle (Δ) and azimuth of each event for each subarray are calculated using the location of the subarray and the following formulas

Event epicentral angle

$$\Delta = \arccos (D1)$$

where

$$D1 = \cos (B1) \cdot \cos (C1) \\ + \sin (B1) \cdot \sin (C1) \cdot \cos (A1)$$



and

$$A1 = (\text{event long.}) + (\text{subarray long.})$$

$$B1 = 90.0^\circ - (\text{event lat.})$$

$$C1 = 90.0^\circ - (\text{subarray lat.})$$

Azimuth of event

$$\text{Azimuth} = \text{Az} (\text{event in NE quadrant})$$

$$\text{Azimuth} = 180^\circ - \text{Az} (\text{event in SE quadrant})$$

$$\text{Azimuth} = 180^\circ + \text{Az} (\text{event in SW quadrant})$$

$$\text{Azimuth} = 360^\circ - \text{Az} (\text{event in NW quadrant})$$

where

$$\text{Az} = | \text{arc sin} (E1) |$$

and

$$E1 = \frac{\sin (A1) \sin (B1)}{\sin (\Delta)}$$

- The expected traveltime from each event to each subarray is determined using a second-order interpolation between the 1° increments given in the Jeffreys-Bullen table
- The traveltime anomaly of each event for each subarray relative to subarray A0 is calculated using the formula

$$A_j = (T_j - H_j) - (T_{A0} - H_{A0})$$

where

T_j is observed arrival time for j^{th} subarray

H_j is computed traveltime to j^{th} subarray



- The horizontal velocity of each event at subarray A0 is interpolated from a table using epicentral angle Δ
- The block in wavenumber space containing an event is computed using the horizontal velocity and azimuth for the event
- After the preceding five steps have been completed for each event, the wavenumber space is searched block by block and, if one or more events are found in a block, the traveltimes anomalies, average anomaly (AVERAGE), and standard deviation (SD) are computed for each subarray. For the j^{th} subarray,

$$\text{AVERAGE} = \frac{1}{N_j} \sum_{\ell=1}^{N_j} A_j^{\ell}$$

$$\text{SD} = \left[\frac{1}{N-1} \sum_{j=1}^N (A_j - \text{AVERAGE})^2 \right]^{1/2}$$

where

N_j is number of events in j^{th} block

A_j^{ℓ} is traveltimes residual for ℓ^{th} event in j^{th} block

Table II-1 summarizes the distribution of the 384 usable events over the 113 blocks within which their epicenters are located. The calculations do not use 22 of the 406 events processed, because the A0 arrival time was not determined. Figure II-2 presents distribution of the events over the wavenumber blocks.

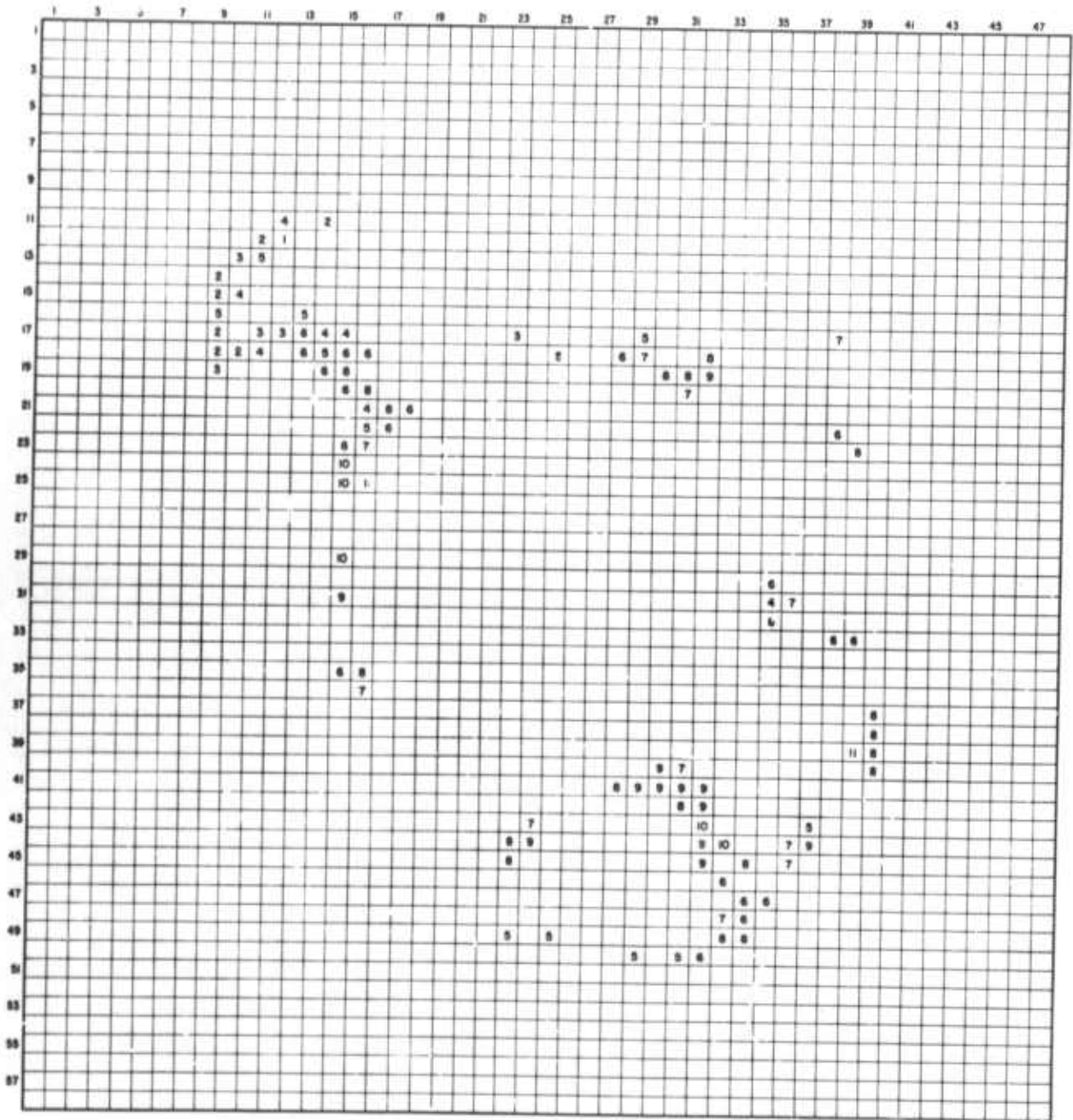


Figure II-2. Number of Events in Each Block



Table II-1

SUMMARY OF DISTRIBUTION OF USABLE EVENTS

<u>No. of Events/Block</u>	<u>No. of Blocks with Given No. of Events</u>	<u>No. of Events</u>
1	45	45
2	20	40
3	14	42
4	9	36
5	5	25
6	5	30
7	6	42
8	2	16
9	1	9
10	1	10
12	1	12
16	2	32
17	1	17
28	<u>1</u>	<u>28</u>
Totals	113	384

C. COMPARISONS OF TRAVELTIME RESIDUALS

Comparison of the traveltime residuals computed for the tele-seismic grid (subsection B) was made using blocks in the Kazakh-Hindu Kush, South American, and Japan-Alaskan regions to determine the

- Difference in each subarray residual for adjacent blocks
- Difference in each subarray residual at 2- and 3-block distances
- Difference over a 3-block region
- Difference in widely separated blocks of the same general region
- Comparison of block residuals to previously computed residuals for the region of interest
- Portion of the time residual due to the different elevation of the LASA subarrays



These comparisons are presented in Tables II-2, II-3, and II-4. The Kazakh-Hindu Kush and South American comparisons were made to determine the differences between time residuals computed for adjacent blocks in wavenumber space and previously computed time residuals for these two regions. Two sets of previously computed time residuals are compared to the set computed for this report. One set was composed of time residuals computed by TI for the Large-Array Signal and Noise Analysis Special Report No. 1* and the other consisted of residuals published in an SDL report.** Many of the events used in the SDL residual calculations were included in the data set used in the calculations for this report. The TI Special Scientific Report No. 1 residuals were calculated from a different set of events.

1. Kazakh-Hindu Kush Comparison

Only one event in the data card library had an epicenter located in block 17,23 — the Kazakh region of the USSR. Residuals computed for this event compared well with the SDL-computed residuals; this was expected, since the SDL Kazakh event ensemble contained this event. Residuals computed for block 18,25 — Hindu Kush region — were identical with the SDL-computed residuals due to a nearly identical data set. Block 18,25 residuals agree much better with the Kazakh residuals computed for TI Special Scientific Report No. 1 than do the residuals for block 17,23; this indicates that the previous TI-calculated residuals contained a number of events from the Hindu Kush region.

* Texas Instruments Incorporated, 1967: A Study of the Relative Capability of Large and Small Seismic Arrays for Event Identification, Large-Array Signal and Noise Analysis, Spec. Rpt. No. 1, Contract AF 33(657)-16678, 20 Apr.

** Seismic Data Laboratory, 1966: LASA Traveltime Anomalies for Various Epicentral Regions, ARPA Order No. 624, 13 Sep.



Table II-2
KAZAKH COMPARISON

Subarray	Time Residuals				Max. -to- Min. Difference	Difference of Residuals							
	Block 17,23	Block 18,25	TI Rpt. No.1 (appendix)	SDL Report		Block 17,23	Block 17,23 TI No.1	Block 17,23 SDL	Block 18,25 TI No.1	Block 18,25 SDL	Block 18,25 TI No.1	Block 18,25 SDL	Block 18,25 SDL Hindu Kush
A0	-	-	-	-	-	-	-	-	-	-	-	-	-
B1	.00	.01	-.04	-.06	.07	.01	.04	.06	.05	.07	.07	.00	.00
B2	.00	.05	.08	-.04	.12	.05	.08	.04	.02	.09	.09	.01	.01
B3	.00	.02	.05	.04	.03	.02	.05	.04	.03	.02	.02	.00	.00
B4	.00	.04	.11	.05	.07	.04	.11	.05	.07	.01	.01	.00	.00
C1	-.08	.03	.07	-.04	.15	.11	.15	.04	.04	.07	.07	.00	.00
C2	-.01	.03	.03	-.10	.13	.04	.04	.09	.00	.13	.13	.00	.00
C3	.01	.15	.16	.02	.15	.14	.15	.01	.01	.13	.13	.00	.00
C4	.09	.20	.25	.13	.16	.11	.16	.04	.05	.07	.07	.00	.00
D1	-	-.03	-.19	-.07	.16	.03	.19	.07	.16	.04	.04	.00	.00
D2	.18	.29	.33	.17	.16	.11	.15	.01	.04	.12	.12	.02	.02
D3	.30	.38	.40	.30	.10	.08	.10	.00	.02	.08	.08	.01	.01
D4	.03	.13	.10	.03	.13	.10	.07	.00	.03	.10	.10	.01	.01
E1	-.16	-.11	-.03	-.17	.14	.05	.13	.01	.09	.06	.06	.01	.01
E2	.09	.28	.26	.11	.15	.19	.17	.02	.02	.17	.17	.01	.01
E3	.52	.59	.67	.51	.16	.07	.15	.01	.08	.08	.08	.00	.00
E4	.53	.71	.65	.64	.18	.18	.12	.11	.06	.07	.07	.03	.03
F1	-.18	-.09	-.07	-.11	.09	.09	.11	.07	.02	.02	.02	.02	.02
F2	.48	.68	.48	.48	.20	.20	.00	.00	.20	.20	.20	.01	.01
F3	.63	.32	.70	.67	.19	.19	.07	.04	.08	.15	.15	.00	.00
F4	.50	.47	.56	.47	.09	.03	.06	.03	.09	.00	.00	.01	.01



Table II-3
SOUTH AMERICAN COMPARISON

Subarray	Time Residuals				Difference of Residuals							
	Block 42,32	Block 41,30	TI Rpt. No. 1 South America	SDL South America	Max. to-Min. Difference	Block 41,31	Blocks 41,30 41,31	Blocks 41,31 42,32	Blocks 41,30 41,31 42,32	Block 41,31 SDL	Block 41,31 TI Rpt. No. 1	Blocks 41,31 44,37
A0	-	-	-	-	-	-	-	-	-	-	-	-
B1	-.01	-.01	-.11	-.02	.10	-.02	.01	.01	.01	.00	.09	.01
B2	.17	.14	.14	.16	.05	.19	.05	.02	.05	.03	.05	.10
B3	-.01	.04	.11	-.01	.12	.01	.03	.00	.05	.00	.10	.06
B4	-.23	-.24	-.07	-.19	.17	-.18	.06	.05	.06	.01	.11	.05
C1	-.31	-.22	-.21	-.28	.10	-.26	.04	.05	.09	.02	.05	.03
C2	.06	.11	.11	.09	.05	.11	.00	.05	.05	.02	.00	.08
C3	.13	.19	.23	.18	.10	.19	.00	.06	.06	.01	.04	.09
C4	-.30	-.22	-.17	-.24	.13	-.23	.01	.07	.08	.01	.06	.03
D1	-.17	-.17	-.14	-.19	.05	-.16	.01	.01	.01	.03	.02	.10
D2	.29	.28	.24	.33	.09	.32	.04	.03	.04	.01	.08	.16
D3	-.13	.03	.03	-.02	.16	-.03	.03	.10	.16	.01	.00	.09
D4	-.62	-.38	-.40	-.46	.22	-.44	.06	.18	.24	.02	.04	.25
E1	-.58	-.26	-.41	-.42	.32	-.41	.15	.17	.32	.01	.00	.44
E2	.32	.39	.41	.40	.09	.41	.02	.09	.09	.01	.00	.19
E3	-.11	.03	.03	-.05	.14	-.05	.08	.06	.14	.00	.02	.10
E4	-.43	.30	-.31	-.33	.13	-.38	.08	.05	.13	.05	.07	.01
F1	-.43	-.23	-.50	-.32	.27	-.32	.09	.09	.20	.00	.18	.49
F2	.14	.15	.06	.15	.09	.15	.00	.01	.01	.00	.09	.05
F3	-.08	-.02	-.10	-.04	.08	-.04	.02	.04	.06	.00	.06	.02
F4	-.10	.09	-.26	.02	.35	.03	.06	.13	.19	.01	.29	.57



Table II-4

RELATIVE ELEVATION OF SUBARRAYS WITH RESPECT TO A0

<u>Subarray</u>	<u>Elevation*</u> <u>(meters)</u>	<u>Max. Time.(msec</u> <u>at 4 km/sec)</u>	<u>Difference between</u> <u>17, 9 and 21, 18</u> <u>(in msec)</u>
A0	—	—	—
B1	+ 10.0	- 2.5	130
B2	- 50.5	12.6	140
B3	- 21.9	5.5	- 10
B4	- 27.8	7.0	140
C1	- 26.4	6.6	150
C2	+ 34.0	- 8.5	190
C3	- 62.0	15.5	70
C4	+ 19.6	- 4.9	120
D1	+ 14.2	- 3.5	300
D2	- 83.7	20.9	80
D3	+ 55.1	-13.8	190
D4	- 30.8	7.5	130
E1	- 58.9	14.7	180
E2	-134.6	33.6	190
E3	+ 16.9	- 4.2	70
E4	+ 58.5	-14.6	10
F1	- 4.3	1.1	- 30
F2	+ 9.9	- 2.5	-160
F3	+ 92.9	-23.2	150
F4	- 37.0	9.2	280

* + is above A0



In comparing the residuals for block 17,23 with those for block 18,25, close agreement was found for only six of the 21 subarrays; the remaining 15 subarrays differed by at least one LASA sample period (50 msec). F4 was the only subarray in the E and F rings differing by less than 50 msec, indicating that traveltime residuals for Asia changed significantly over a 2- to 3-block region. Traveltime residuals for the E and F rings generally have a larger mean and variance than the residuals computed for the lower rings.

2. South American Comparison

Of the four wavenumber blocks used for comparison in the South American region, three were adjacent to each other and covered the Northern Argentina-Chile border region. The fourth was seven blocks away and covered part of the Venezuelan coast.

Block 41,21 in the center of the 3-block group showed extremely close correspondence with the SDL time residuals computed for this region; this was expected, since most of the events used were common to both computations. Block 41,21 did not correspond as well with blocks 41,30 or 42,32 as it did with the SDL Northern Argentina-Chile residuals. A similar change in traveltime residuals for adjacent epicentral regions in South America can be observed in the SDL-computed traveltime residuals. The differences in traveltime residuals within the 3-block group were almost as great as the differences between blocks 41,31 and 44,37, which were about six blocks apart. This indicates degradation in wavenumber resolution when several adjacent blocks within the South American region are corrected with the same set of traveltime residuals.

3. Traveltime Residuals Due to Subarray Elevation

As shown in Figure II-3, the number of subarrays in a block needing a traveltime correction decreases as the wavenumber increases.

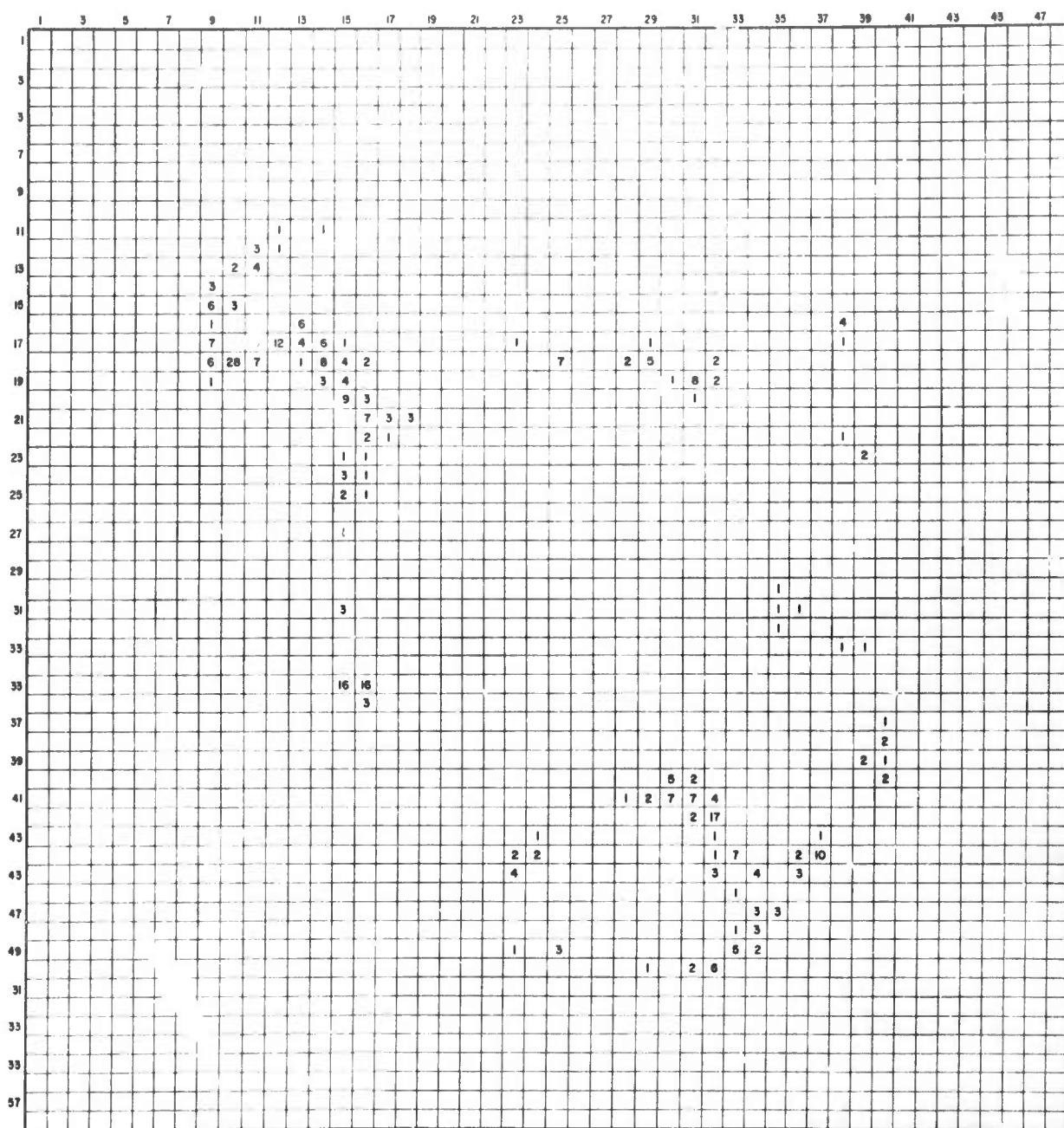


Figure II-3. Number of Subarrays Needing Correction (B, C, and D Rings)



This indicates that events from distant epicenters require traveltime corrections for a greater number of subarrays than do events of closer epicenter, even though the distant events have a higher apparent velocity across the array. It was thought that this phenomenon might be explained by a difference in elevation between each subarray and the reference subarray.

Table II-4 summarizes the differences in elevation and the corresponding traveltimes in a medium with a 4-km/sec propagation velocity. These computed traveltimes are compared with the difference in traveltime residuals computed for blocks 17, 9 and 21, 18. The theoretical traveltime anomalies due to elevation are insignificant compared with anomaly differences actually experienced.

D. OBSERVATIONS IN USING ANOMALIES

Experience in computing high-resolution wavenumber spectra at LASA indicates that regional corrections for traveltime anomalies are usually needed to detect a signal using the full LASA. The computed subarray spectra usually can detect signals without anomaly corrections. Generally, the effect of traveltime anomalies on intermediate-size arrays (diameters from 20 to 60 km) cannot be evaluated using the currently available anomaly data. These effects will be investigated using data from the E3 extended subarray and from a LASA configuration consisting of the A, B, C, and D rings of subarray outputs.

E. CONCLUSIONS ABOUT ANOMALIES

From the traveltime anomalies investigated, the following general observations were made:

- Variations in traveltime residuals for adjacent blocks were of the order of the standard deviation of the data in each block



- Variations between blocks in a 3- to 5-block region were greatest for events coming from South America
- Differences in subarray residuals for blocks separated by three or more blocks were greater than the standard deviation of the data in each block
- Only 113 blocks contained events and, of these, only 25 had five or more events
- Subarrays in the LASA E and F rings generally had larger means and standard deviations in their calculated residuals than did the inner-ring subarrays
- Comparison with SDL was very good due to common data
- Relative differences in subarray elevation had no significant effect on the traveltime residuals
- Comparison with previous TI-computed residuals was not good due to the large areas used in previous calculations.

Variability of the mean traveltime residuals was small enough to permit computation of average residuals for multiple block regions. This was confirmed in Special Scientific Report No. 1 where a large region was considered when computing residuals.*

The data currently available are inadequate for the design of a reasonable scheme to correct wavenumber spectra calculations for traveltime anomalies. This was apparent from the wavenumber distribution of the available events. Large areas of interest completely lacked events. Before any reasonable correction scheme can be devised, more higher-quality data must be available.

*Op cit



If the wavenumber spectra calculations are not corrected for traveltime anomalies, the subarrays on the LASA E and F rings should not be included in the calculations due to their generally large traveltime residuals. Other arguments for not including these subarrays when calculating wavenumber spectra are presented in the following sections.



SECTION III SMOOTHING MOVEOUT ANALYSIS

High-resolution wavenumber spectra are generated by using a discrete Fourier transform such as the Cooley-Tukey algorithm to transform the time-domain data to the frequency domain before estimating the auto- and crosspower spectra. This section uses simple models to analyze the spectral window and the effective signal-to-noise improvement experienced when generating high-resolution spectra from LASA data.

By estimating the crosspower spectrum of two sensors in a seismic array from the direct Fourier transform of the individual time traces, a spectral window effect is produced in the estimate. Under the simple assumptions of uniform plane-wave propagation across the array and a boxcar smoothing in the direct transform, this spectral window is expressed as

$$\frac{\sin\left(\pi \frac{t_{ij}}{T}\right)}{\left(\pi \frac{t_{ij}}{T}\right)} \quad (3-1)$$

where T is the length of the data trace transformed and t_{ij} is the moveout between the i^{th} and j^{th} channel. If the energy across the smoothing window is uniformly distributed, the phase of the crosspower spectrum is unaffected by the spectral window. This interpretation (i. e., processing) of a crosspower spectrum using only the phase information becomes ambiguous when there is more than one plane wave.

To reduce the spectral window for a fixed maximum expected moveout requires that the transform gate length be increased. Similarly, to maintain the same spectral window for an increased maximum moveout also requires an increased transform gate length. This increase in transform



gate length reduces the effective signal-to-noise ratio for the transient seismic signal being considered. In both cases, the decrease in effective signal-to-noise ratio can be offset by adding more sensors within the array.

Although the following development treats the simple cases just discussed, the results are helpful in eliminating gross errors when generating crosspower estimates from direct transforms.

A. DEVELOPMENT OF WINDOW FUNCTION

Consider two sensors S_i and S_j separated by distance d_{ij} in a seismic array. When a uniform plane wave propagates across the array with an apparent velocity of v_{ij} along d_{ij} , moveout (traveltime) t_{ij} between S_i and S_j is

$$t_{ij} = \frac{d_{ij}}{v_{ij}} \quad (3-2)$$

We let θ_p be the angle made by the line d_{ij} with the direction of propagation of the plane wave. Then, for a plane wave with velocity v_p , apparent velocity v_{ij} is

$$v_{ij} = \frac{v_p}{\cos \theta_p} \quad (3-3)$$

Moveout t_{ij} is then

$$t_{ij} = \frac{d_{ij}}{v_p} \cos \theta_p \quad (3-4)$$

For a particular v_p , the largest moveout which can be experienced in a multisensor array occurs between sensors with the widest separation when the wavefronts are propagating in the direction of separation (i.e., $\theta_p = 0$). Later, we will show that the largest expected moveout constrains the data processing.



The crosspower spectrum between S_i and S_j is then

$$\phi_{ij}(f) = M \exp(J 2\pi f t_{ij}) \quad (3-5)$$

Here, we assume that the estimation process can be represented as a boxcar smoothing applied over an interval

$$f_a \leq f_o \leq f_b \quad (3-6)$$

The estimated crosspower at frequency f_o is

$$\bar{\phi}_{ij} = \frac{M}{(f_b - f_a)} \int_{f_a}^{f_b} \exp(J 2\pi f t_{ij}) df \quad (3-7)$$

Carrying out the indicated integration gives

$$\bar{\phi}_{ij} = \frac{-JM}{2\pi t_{ij} (f_b - f_a)} \left[\exp(J 2\pi t_{ij} f_b) - \exp(J 2\pi t_{ij} f_a) \right] \quad (3-8)$$

Then, the real and imaginary parts of Equation 3-8 are

$$\text{Re } \bar{\phi}_{ij} = \frac{M}{2\pi t_{ij} (f_b - f_a)} \left[\sin 2\pi t_{ij} f_b - \sin 2\pi t_{ij} f_a \right] \quad (3-9)$$

and

$$\text{Im } \bar{\phi}_{ij} = \frac{M}{2\pi t_{ij} (f_b - f_a)} \left[\cos 2\pi t_{ij} f_a - \cos 2\pi t_{ij} f_b \right] \quad (3-10)$$



By employing the trigonometric identities

$$\sin a - \sin b = 2 \cos \left(\frac{a+b}{2} \right) \sin \left(\frac{a-b}{2} \right)$$

and

$$\cos b - \cos a = 2 \sin \left(\frac{a+b}{2} \right) \sin \left(\frac{a-b}{2} \right)$$

we can write Equations 3-9 and 3-10 as

$$\operatorname{Re} \bar{\phi}_{ij} = \frac{M}{\pi t_{ij} (f_b - f_a)} \left\{ \cos \left[\pi t_{ij} (f_a + f_b) \right] \sin \left[\pi t_{ij} (f_b - f_a) \right] \right\} \quad (3-11)$$

and

$$\operatorname{Im} \bar{\phi}_{ij} = - \frac{M}{\pi t_{ij} (f_b - f_a)} \left\{ \sin \left[\pi t_{ij} (f_b + f_a) \right] \sin \left[\pi t_{ij} (f_b - f_a) \right] \right\} \quad (3-12)$$

The magnitude of the crosspower estimate at frequency f_0 is then

$$|\bar{\phi}_{ij}| = M \frac{\sin \pi t_{ij} (f_b - f_a)}{\pi t_{ij} (f_b - f_a)} \quad (3-13)$$

and the phase of the same function is

$$\arg \bar{\phi}_{ij} = \pi t_{ij} (f_b + f_a) \quad (3-14)$$

In general, the transform algorithms used in the estimation process have a constant-width smoothing function; i. e., $f_b - f_a = \Delta f =$ a constant. Thus, Equation 3-13 can be written

$$|\bar{\phi}_{ij}| = M \frac{\sin \pi t_{ij} \Delta f}{\pi t_{ij} \Delta f} \quad (3-15)$$



B. APPLICATION TO SEISMIC ARRAYS

The smoothing-moveout window functions are present in the frequency-domain processing of a seismic array when the auto-crosspower matrix is being estimated. Usually, the processed seismic data are broadband, with the energy nearly uniformly distributed in a small band Δf ; in this case, the crosspower phase estimated by Equation 3-14 will be a very good estimate of the actual phase, but the smoothing-moveout window function still will be present in the magnitude of the crosspower spectra estimated by Equation 3-15.

The effect of this window function is minimized when the product $t_{ij} \Delta f$ is minimized. To maintain all of the estimated auto- and crosspower spectra within 10 percent of each other, the function

$$\frac{\sin \pi t_m \Delta f}{\pi t_m \Delta f} \geq 0.9 \quad (3-16)$$

for the largest expected moveout t_m . This requires that

$$t_m \Delta f \leq \frac{1}{4} \quad (3-17)$$

These estimates are obtained from the transforms of data segments T -sec long. The smallest Δf obtainable with a segment of length T is approximately

$$\Delta f \cong \frac{1}{T} \quad (3-18)$$

This implies that

$$T \geq 4 t_m$$

The length of the data segment transformed should be at least four times the largest expected moveout across the array.



In the single plane-wave case just considered, it appears that the window effect could be circumvented for $\Delta t < t_{ij} < \pi$ by normalizing the auto- and crosspower spectra; this would sacrifice information about the waveform amplitude for a better estimate of its crosspower. This normalizing can result in incorrect interpretation when two or more plane-wave signals of different velocities are present in the transform gate.

For two plane waves with moveouts t_1 and t_2 , respectively, the crosspower at frequency f is

$$\begin{aligned} \phi(f) = & M_1^2 \exp j 2\pi f t_1 + M_2^2 \exp j 2\pi f t_2 \\ & + M_1 M_2 \exp j 2\pi f (t_1 - t_2) \\ & + M_1 M_2 \exp j 2\pi f (t_2 - t_1) \end{aligned} \quad (3-19)$$

where M_1 and M_2 are the respective amplitudes of the waves. The estimated crosspower can be expressed by integrating each term of Equation 3-19 over the interval f_a to f_b and operating on each term with the trigonometric identities in subsection A. The estimated crosspower for $\Delta f = f_b - f_a$ is then

$$\begin{aligned} \bar{\phi} = & \left(\frac{\sin \pi t_1 \Delta f}{\pi t_1 \Delta f} \right) M_1^2 \exp j \pi t_1 (f_a + f_b) \\ & + \left(\frac{\sin \pi t_2 \Delta f}{\pi t_2 \Delta f} \right) M_2^2 \exp j \pi t_2 (f_a + f_b) \\ & + \left(\frac{\sin \pi (t_1 - t_2) \Delta f}{\pi (t_1 - t_2) \Delta f} \right) M_1 M_2 \exp \left\{ \left[j \pi (t_1 - t_2) (f_a + f_b) \right] \right. \\ & \left. + \exp \left[-j \pi (t_1 - t_2) (f_a + f_b) \right] \right\} \end{aligned} \quad (3-20)$$



if the signals are wideband and the energy is uniformly distributed over the interval Δf , then $(f_a + f_b)$ is very close to $2f_0$ where f_0 is the transform frequency point. The estimated crosspower then contains every term of the true crosspower, with each term multiplied by its own window function. By making Δf small, the window effects can be reduced and a reasonably good estimate obtained.

C. INCREASED GATE LENGTH'S EFFECTS ON CROSSPOWER ESTIMATES

Current applications of frequency-domain processing employ direct transforms of the time-domain data to estimate auto- and crosspower spectra. Since the transform algorithms (such as Cooley-Tukey) are finite and discrete, their outputs are functions of the energy rather than the power contained in the data segment transformed; this is especially true in seismic work where the signals being processed are transients.

Consider the transforms X_a and X_b of two data channels containing signal and additive noise. Then,

$$X_a = S_a + N_a$$

and

$$X_b = S_b + N_b$$

If the data segment is of length T , the computed transform points will have a frequency resolution limit (spectral window) of Δf_1 where

$$\Delta f_1 \approx \frac{1}{T}$$



The autopower spectrum of each channel is then estimated as the energy density spectrum

$$\bar{\phi}_a = X_a X_b^* = [S_a S_a^* + S_a N_a^* + N_a S_a^* + N_a N_a^*]$$

$$\bar{\phi}_b = X_b X_b^* = [S_b S_b^* + S_b N_b^* + N_b S_b^* + N_b N_b^*]$$

Similarly, the crosspower spectrum is estimated from the cross-energy density spectrum

$$\bar{\phi}_{ab} = X_a X_b^* = [S_a S_b^* + S_a N_b^* + N_a S_b^* + N_a N_b^*]$$

In these expressions,

$$S_i S_i^* = \text{signal energy in channel } i$$

$$N_i N_i^* = \text{noise energy in channel } i$$

$$S_i S_j^* = \text{signal energy common to } i \text{ and } j \text{ data channels}$$

$$N_i N_j^* = \text{noise energy common to } i \text{ and } j \text{ data channels}$$

For transient signals with an effective signal duration of $t_g < T$, the band Δf_g over which the signal energy is distributed in frequency is greater than $1/t_g$. A resolved band Δf_1 in the frequency range of the signal energy will contain some fraction of the total signal energy present in the data segment. If the data segment containing this signal is doubled in length ($2T$), the frequency resolution limit $\Delta f_2 = 0.5 \Delta f_1$.



The total signal energy in the long segment is the same as the total signal energy in the short segment. A resolved band Δf_2 in the frequency range of the signal energy will then have half the average energy that a resolved band Δf_1 would have at the same frequency. Figure III-1 shows a typical signal energy spectrum.

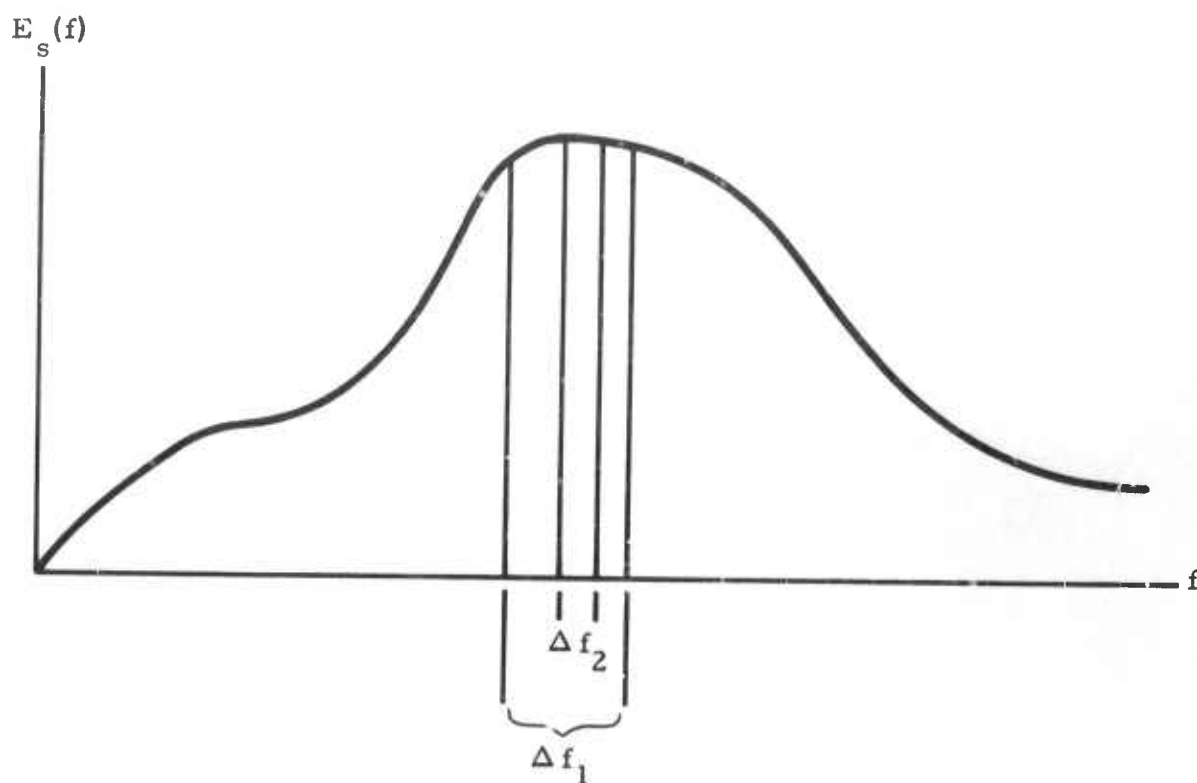


Figure III-1. Typical Signal Energy Spectrum

To be more precise, let $E_S(f)$ be the true energy density spectrum of the signal in the data segment. The signal energy in a resolved band is

$$E_S(\Delta f) = \int_{\Delta f} E_S(f) df$$



So, if

$$\Delta f_1 = 2\Delta f_2$$

then

$$E_S (\Delta f_1) \approx 2 E_S (\Delta f_2)$$

Seismic noise is generally considered to be the output of a Gaussian process. Doubling the data gate length will then double the total noise energy in the data segment. The average noise energy in the resolved band Δf_2 using a double-length (2T) data segment will then be the same as the average noise energy in the resolved band Δf_1 of the single-length (T) data segment; i. e.,

$$E_N (\Delta f_1) \approx E_N (\Delta f_2)$$

If the applicable signal-to-noise ratio is considered to be the ratio of signal energy to noise energy in a data segment, doubling the data gate length reduces the signal-to-noise ratio by one-half:

$$\frac{E_S (\Delta f_2)}{E_N (\Delta f_2)} = \frac{1}{2} \left[\frac{E_S (\Delta f_1)}{E_N (\Delta f_1)} \right]$$

This is true whenever signal duration t_s is less than the data gate lengths being transformed.

D. LASA PROCESSING CONSIDERATIONS

Results of the previous analysis on the computation of high-resolution wavenumber spectra for the Montana LASA may be applied by considering the beamsteered improvement in signal-to-noise power. This approach is useful because the computation of standard wavenumber spectra is



the frequency-domain equivalent to time-shift-and-sum beam-forming followed by square-law detecting. In the frequency-domain processing considered, all time-domain data are transformed to the frequency domain before the performance of any beamsteering or other processing. The relative signal-to-noise gain for various LASA configurations will then give a general picture of the manner in which configuration and moveout constrain the processing.

To limit the extent of this comparison, the array configurations include all of the subarrays within and on the LASA ring under consideration. Thus, there are five array configurations for the B through the F rings. The signals of interest have greater than 10-km/sec apparent velocity across the array, so the maximum expected moveout for each configuration is

$$t_{m,j} = \frac{d_j}{10 \text{ km/sec}}$$

where d_j is the diameter of the j^{th} ring.

If the array is enlarged by adding all of the subarrays on the next ring out, the transform gate length T_j must be increased to maintain the same spectral window; this increases the transform gate length to

$$T_{j+1} = \left(\frac{t_{m,j+1}}{t_{m,j}} \right) T_j = \left(\frac{d_{j+1}}{d_j} \right) T_j$$

The loss in effective signal-to-noise ratio due to the increase in gate length is then

$$L_{j+1} = \frac{T_j}{T_{j+1}} = \frac{d_j}{d_{j+1}}$$



As the array is expanded, more sensors are added. Assuming that the seismic noise field is uncorrelated from subarray to subarray, the beamsteered signal-to-noise power gain of the j^{th} array over a single subarray is

$$G_j = N_j = \text{number of subarrays in } j^{\text{th}} \text{ configuration}$$

The total gain (or loss) obtained by adding one ring to the j^{th} array configuration is then

$$H_{j+1,j} = L_{j+1} \left(\frac{G_{j+1}}{G_j} \right) = \left(\frac{d_j}{d_{j+1}} \right) \left(\frac{N_{j+1}}{N_j} \right)$$

As successively larger rings are added to the beamsteering process, the signal-to-noise improvement predicted for LASA increases with the increase in the number of subarrays and decreases with the increase in aperture. This function is plotted in Figure III-2.

This analysis indicates a serious drawback in using rings outside the C ring for frequency-domain signal processing. To include the D ring reduces the beamsteer gain 20 percent, while the E and F rings reduce the beamsteer gain 50 and 60 percent, respectively. These decreases result from doubling the array aperture while not doubling the number of subarrays.

In the light of this analysis, the use of subarrays on the E and F rings when computing high-resolution wavenumber spectra for LASA does not appear advantageous.



<u>Ring</u>	<u>Diameter (km)</u>	<u>No. of Sensors</u>	<u>Gain Over Last Ring</u>
B	18	4	5
C	31	4	1.05
D	58	4	0.77
E	120	4	0.64
F	200	4	0.74



Figure III-2. Signal-to-Noise Improvement



SECTION IV CONCLUSIONS

From this study, there are two major conclusions:

- Current data are insufficient to define a scheme adequately to correct wavenumber spectra calculations for traveltime anomalies
- Subarrays on the E and F rings of LASA will not be included in high-resolution $f\text{-}\vec{k}$ spectra calculations

Subarrays on the E and F rings of LASA generally exhibit larger traveltime residuals and less waveform similarity than do subarrays of the inner rings. * Current data appear to be inadequate to describe these anomalies with any degree of certainty. With this lack of knowledge of the anomaly mechanism, coupled with the spectral window considerations, the use of subarrays on the E and F rings of LASA is unadvisable.

* Texas Instruments Incorporated, 1967: Short-Period Signal Waveform at LASA, Large-Array Signal and Noise Analysis, Spec. Rpt. No. 8, Contract AF 33(657)-16678, 1 Aug.



APPENDIX A
TRAVELTIME RESIDUALS

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BLOCK NO = (11.12) NO OF EVENTS = 1

SUBARRAY	MEAN	STD. DEVIATION
R1	0.1125	
R2	0.0011	
R3	0.0000	
R4	-0.0265	
C1	0.0566	
C2	0.0471	
C3	-0.0241	
C4	-0.0874	
D1	0.1241	
D2	-0.0962	
D3	-0.1890	
D4	0.0072	
<hr/>		
F1	-0.0294	
F2	-0.0149	
F3	0.0000	
F4	-0.1890	
<hr/>		
F1	0.0534	
F2	-0.2309	
F3	-0.1145	
F4	0.0000	

BLOCK NO = (11.14) NO OF EVENTS = 1

SUBARRAY	MEAN	STD. DEVIATION
R1	-0.0512	
R2	0.0314	
R3	-0.0451	
R4	-0.0642	
C1	-0.0129	
C2	-0.0125	
C3	-0.0022	
C4	-0.0449	
D1	-0.0016	
D2	-0.2048	
D3	-0.1122	
D4	-0.0461	
<hr/>		
E1	-0.1185	
F2	-0.0375	
F3	-0.2282	
F4	-0.1633	
<hr/>		
F1	0.1013	
F2	-0.3242	
F3	-0.1322	
F4	-0.2651	

Source: Business Form No. 5, Dec. 1954

BLOCK NO = (12.11)

NO OF EVENTS = 1

SUBARRAY	MEAN	STD. DEVIATION
R1	0.0267	0.0000
R2	0.0700	0.0000
R3	-0.0682	0.0941
R4	0.0272	0.0398
C1	-0.0388	0.0000
C2	0.0747	0.0906
C3	-0.0560	0.0955
C4	-0.0041	0.0139
D1	0.0463	0.0472
D2	-0.0468	0.0731
D3	-0.0946	0.0953
D4	0.0835	0.0856
E1	-0.1778	0.1890
E2	-0.1321	0.1321
F3	-0.1701	0.0868
F4	-0.0893	0.0483
F1	-0.0276	0.0493
F2	-0.2429	0.0917
F3	-0.1091	0.0730
F4	-0.0355	0.0406

BLOCK NO = (12.12)

NO OF EVENTS = 1

SUBARRAY	MEAN	STD. DEVIATION
R1	0.0499	
R2	0.0529	
R3	-0.0631	
R4	-0.0329	
C1	0.0180	
C2	0.0595	
C3	-0.0589	
C4	-0.0787	
D1	0.0072	
D2	0.0000	
D3	-0.1917	
D4	0.0000	
F1	-0.2080	
F2	0.0967	
F3	-0.1783	
F4	-0.1766	
F1	-0.0375	
F2	-0.3228	
F3	-0.1791	
F4	-0.2544	

4

3

BLOCK NO = (13.10)

NO OF EVENTS = 2

SUBARRAY	MEAN	STD. DEVIATION
R1	0.0606	0.0356
R2	0.0457	0.0017
R3	-0.0393	0.0573
R4	0.0235	0.0011
C1	0.0841	0.0882
C2	0.0012	0.0522
C3	-0.0295	0.1178
C4	-0.0182	0.1294
D1	0.1398	0.0603
D2	-0.0270	0.0253
D3	-0.1459	0.0398
D4	0.0233	0.0550
<hr/>		
F1	-0.0552	0.0288
F2	-0.0375	0.0079
F3	-0.2435	0.0011
F4	-0.1788	0.0984
<hr/>		
F1	-0.0767	0.1714
F2	-0.4108	0.0501
F3	-0.1001	0.1129
F4	0.0049	0.1340

BLOCK NO = (13.11)

NO OF EVENTS = 4

SUBARRAY	MEAN	STD. DEVIATION
R1	0.0987	0.0728
R2	0.0473	0.0587
R3	-0.1413	0.2051
R4	0.0374	0.0305
C1	0.0698	0.0516
C2	0.1166	0.0937
C3	-0.0529	0.0734
C4	-0.0545	0.0162
D1	0.1308	0.0369
D2	-0.0454	0.0845
D3	-0.1001	0.1217
D4	0.0605	0.0378
<hr/>		
F1	0.0000	-0.0000
F2	0.0050	0.0000
F3	-0.0132	0.0000
F4	-0.2421	0.2035
<hr/>		
F1	-0.0143	0.0627
F2	-0.3430	0.2841
F3	-0.0894	0.0000
F4	-0.1249	0.2130

BLOCK NO = 115. 91

SUBARRAY	MEAN	STD. DEVIATION
B1	0.0362	0.0000
B2	0.0879	0.0000
B3	-0.0640	0.0300
B4	-0.0080	0.0000
C1	0.0463	0.1800
C2	0.0288	0.0974
C3	0.0294	0.0730
C4	-0.0217	0.0271
D1	0.2352	0.0000
D2	-0.0772	0.0859
D3	-0.0581	0.0349
D4	0.0324	0.0359
F1	0.0497	0.0882
F2	0.0285	0.0632
F3	-0.1292	0.1618
F4	-0.1966	0.1146
F1	0.0881	0.0178
F2	-0.1828	0.0300
F3	0.2248	0.0641
F4	-0.0508	0.0271

BLOCK NO = 115. 91 NO OF EVENTS = 6

SUBARRAY	MEAN	STD. DEVIATION
B1	0.0305	0.0548
B2	0.0144	0.0854
B3	-0.0712	0.0485
B4	-0.0684	0.0492
C1	0.0539	0.0302
C2	0.0182	0.0779
C3	-0.0480	0.0563
C4	-0.1593	0.0582
D1	0.1081	0.0898
D2	0.0217	0.0271
D3	-0.0496	0.0554
D4	0.0000	0.0518
F1	-0.1000	0.0700
F2	0.0541	0.1091
F3	-0.2112	0.0826
F4	-0.1000	0.0700
F1	0.0450	0.0951
F2	-0.1613	0.0422
F3	-0.0647	0.1439

BLOCK NO = (15.10) NO OF EVENTS =

SUBARRAY	MEAN	STD. DEVIATION
B1	0.0603	0.0000
B2	0.1058	0.0000
B3	-0.0017	0.0000
B4	0.0006	0.0272
C1	0.1537	0.1587
C2	0.1602	0.1692
C3	0.0054	0.0000
C4	-0.0569	0.0534
D1	0.1831	0.0405
D2	0.0337	0.0474
D3	0.0116	0.0154
D4	-0.0010	0.0617
<hr/>		
F1	-0.0024	0.0584
F2	0.1184	0.0000
F3	0.0000	-0.0000
F4	-0.2190	0.2370
<hr/>		
F1	0.1543	0.1545
F2	-0.1759	0.0000
F3	0.1386	0.1650
F4	-0.0589	0.0594

BLOCK NO = (16. 9) NO OF EVENTS = 1

SUBARRAY	MEAN	STD. DEVIATION
B1	-0.0980	
B2	-0.0727	
B3	-0.1312	
B4	0.0133	
C1	-0.1438	
C2	-0.0017	
C3	0.0000	
C4	0.0449	
D1	-0.0256	
D2	-0.0626	
D3	0.0143	
D4	-0.0964	
<hr/>		
F1	-0.0462	
F2	0.0260	
F3	-0.2531	
F4	-0.1743	
<hr/>		
F1	-0.0545	
F2	-0.4144	
F3	0.0350	
F4	-0.2811	

BLOCK NO = (16.13) NO OF EVENTS = 6

SUBARRAY	MEAN	STD. DEVIATION
B1	-0.0984	0.1083
B2	0.0764	0.0462
B3	0.0150	0.0322
B4	-0.0358	0.0329
C1	-0.0333	0.0214
C2	-0.1111	0.1547
C3	0.0698	0.0325
C4	-0.0348	0.0411
D1	-0.1988	0.0451
D2	-0.1519	0.0788
D3	-0.1238	0.0718
D4	-0.0017	0.0500
<hr/>		
F1	-0.1852	0.1597
F2	-0.1374	0.0756
F3	-0.2554	0.0381
F4	-0.0237	0.0544
<hr/>		
F1	0.0000	-0.0000
F2	-0.4501	0.0684
F3	-0.1066	0.0684
F4	-0.2504	0.1267

BLOCK NO = (10.30) NO OF EVENTS = 4

SUBARRAY	MEAN	STD. DEVIATION
B1	-0.0565	0.0520
B2	-0.1850	0.2620
B3	-0.0367	0.0610
B4	0.0166	0.0597
C1	-0.0534	0.0000
C2	-0.1448	0.2077
C3	-0.3952	0.0000
C4	0.0091	0.0858
D1	-0.1209	0.0937
D2	-0.4973	0.7034
D3	-0.1799	0.1296
D4	-0.0191	0.0000
<hr/>		
F1	0.0171	0.0436
F2	-0.0901	0.0458
F3	-0.4828	0.3427
F4	-0.4573	0.0000
<hr/>		
F1	0.3189	0.4589
F2	-0.5657	0.1001
F3	-0.8162	0.0000
F4	-0.2509	0.0000

BLOCK NO = (17. 91)

NO OF EVENTS = 7

SUBARRAY	MEAN	STD. DEVIATION
R1	0.0686	0.1417
R2	0.0781	0.0758
R3	-0.0500	0.0535
R4	-0.0359	0.0380
C1	0.0590	0.0770
C2	0.1214	0.0923
C3	0.0023	0.0223
C4	-0.0390	0.0592
D1	0.2519	0.1590
D2	-0.0752	0.1029
D3	-0.0250	0.0658
D4	0.0126	0.0381
F1	0.0585	0.0684
F2	0.1539	0.1070
F3	-0.2297	0.1116
F4	-0.1422	0.0654
F1	0.1041	0.0535
F2	-0.4444	0.2008
F3	-0.2212	0.0445
F4	-0.1898	0.0617

BLOCK NO = (17.111)

NO OF EVENTS = 4

SUBARRAY	MEAN	STD. DEVIATION
B1	0.0247	0.0976
B2	0.0485	0.0000
B3	-0.1228	0.1751
B4	-0.0371	0.0813
C1	0.0136	0.0946
C2	0.0019	0.0246
C3	-0.0582	0.0776
C4	-0.0609	0.0930
D1	-0.0736	0.0699
D2	-0.0983	0.1032
D3	-0.1525	0.1139
D4	-0.0224	0.0771
F1	-0.1731	0.0484
F2	-0.0742	0.0284
F3	-0.3934	0.1161
F4	-0.1432	0.0618
F1	-0.2502	0.3544
F2	-0.5291	0.0609
F3	-0.3493	0.0852
F4	0.3023	0.0471

BLOCK NO = (17.12) NO OF EVENTS = 12

SUBARRAY	MEAN	STD. DEVIATION
R1	-0.0297	0.0412
R2	0.0204	0.0782
R3	-0.0667	0.0747
R4	-0.0439	0.0607
C1	0.0454	0.0809
C2	-0.0366	0.0574
C3	-0.0247	0.0431
C4	-0.0795	0.0514
D1	-0.0881	0.0528
D2	-0.1187	0.0808
D3	-0.1533	0.1075
D4	-0.0184	0.0593
<hr/>		
F1	-0.1304	0.0467
F2	-0.0609	0.0742
F3	-0.3840	0.2944
F4	-0.1351	0.0540
<hr/>		
F1	-0.2975	0.1577
F2	-0.5266	0.1810
F3	-0.3173	0.2944
F4	-0.3095	0.1198

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1

BLOCK NO = (17.13) NO OF EVENTS = 4

SUBARRAY	MEAN	STD. DEVIATION
R1	-0.0883	0.0789
R2	0.1020	0.1473
R3	0.0306	0.0543
R4	-0.0441	0.0191
C1	-0.0211	0.0278
C2	-0.0647	0.0491
C3	0.0708	0.0364
C4	-0.0067	0.0358
D1	-0.2199	0.1742
D2	-0.1693	0.0276
D3	-0.0811	0.0377
D4	0.0874	0.0905
<hr/>		
F1	-0.2018	0.0116
F2	-0.0650	0.1178
F3	-0.2892	0.0443
F4	-0.0185	0.0418
<hr/>		
F1	-0.2740	0.0000
F2	-0.4059	0.0290
F3	-0.1167	0.0468
F4	-0.2890	0.2044

BLOCK NO = (17.14)

NO OF EVENTS = 6

SUBARRAY	MEAN	STD. DEVIATION
R1	-0.0972	0.2064
R2	0.0238	0.0639
R3	0.0089	0.0282
R4	-0.0435	0.0648
C1	-0.0293	0.0499
C2	-0.0279	0.0386
C3	0.0424	0.0529
C4	0.0037	0.0310
D1	-0.2145	0.1791
D2	-0.1887	0.0993
D3	-0.0955	0.0540
D4	0.0553	0.0353
<hr/>		
F1	-0.2727	0.0341
F2	-0.1169	0.0799
F3	-0.2719	0.2299
F4	0.0193	0.0865
<hr/>		
F1	-0.2902	0.2399
F2	-0.4564	0.3546
F3	-0.1826	0.0967
F4	-0.2527	0.0775

BLOCK NO = (17.15)

NO OF EVENTS = 1

SUBARRAY	MEAN	STD. DEVIATION
R1	0.0000	
R2	0.0000	
R3	0.0000	
R4	0.0000	
C1	-0.0867	
C2	-0.0881	
C3	0.0794	
C4	-0.0123	
D1	-0.2192	
D2	0.0000	
D3	-0.0937	
D4	0.0555	
<hr/>		
F1	-0.1703	
F2	-0.1722	
F3	-0.3299	
F4	0.0000	
<hr/>		
F1	-0.2735	
F2	-0.4484	
F3	-0.2457	
F4	-0.0429	

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BLOCK NO = (117.23) NO OF EVENTS = 1

SUBARRAY MEAN STD. DEVIATION

B1 0.0000

B2 0.0000

B3 0.0000

B4 0.0000

C1 0.0986

C2 0.0095

C3 -0.0050

C4 -0.0917

D1 0.0000

D2 -0.1782

D3 -0.3060

D4 -0.0299

F1 0.1566

F2 -0.0916

F3 -0.5244

F4 -0.5295

F1 0.1769

F2 -0.4795

F3 -0.6302

F4 -0.4951

BLOCK NO = (17.29) NO OF EVENTS = 1

SUBARRAY MEAN STD. DEVIATION

B1 -0.0081

B2 -0.1384

B3 -0.0071

B4 -0.0346

C1 -0.1731

C2 -0.2545

C3 -0.2490

C4 -0.0303

D1 -0.0356

D2 -0.4087

D3 -0.0854

F1 0.0000

F2 -0.4344

F3 -0.3756

F4 -0.3932

F1 -0.3879

F2 -0.8711

F3 -0.7343

F4 -0.8920

BLOCK NO = (17.38)

NO OF EVENTS = 1

SUBARRAY	MEAN	STD. DEVIATION
R1	-0.0389	
R2	-0.2856	
R3	-0.0495	
R4	0.0481	
C1	-0.0849	
C2	-0.1847	
C3	-0.4379	
C4	0.0127	
D1	-0.1235	
D2	-0.5048	
D3	-0.1901	
D4	-0.0454	
<hr/>		
F1	0.0321	
F2	-0.1003	
F3	-0.4625	
F4	-0.2900	
<hr/>		
F1	0.3781	
F2	-0.5891	
F3	-0.9092	
F4	-0.2170	

BLOCK NO = (18.9)

NO OF EVENTS = 4

SUBARRAY	MEAN	STD. DEVIATION
B1	-0.0108	0.0575
B2	0.0757	0.0836
B3	-0.0395	0.0411
B4	-0.0668	0.0485
C1	0.0531	0.0563
C2	0.0559	0.0733
C3	-0.0021	0.0401
C4	-0.0681	0.0387
D1	0.1570	0.0734
D2	-0.0827	0.1258
D3	-0.0414	0.0733
D4	-0.0197	0.0527
<hr/>		
F1	0.0924	0.0632
F2	0.0306	0.0715
F3	-0.2291	0.0830
F4	-0.0456	0.0577
<hr/>		
F1	-0.0128	0.0591
F2	-0.5861	0.3033
F3	-0.1737	0.0856
F4	-0.1290	0.0132

SUBARRAY MEAN STD. DEVIATION

R1	0.0788	0.0700
R2	0.0793	0.0600
R3	-0.0586	0.0700
R4	-0.0489	0.0559
C1	0.0783	0.0700
C2	0.0789	0.0600
C3	-0.0737	0.0752
C4	-0.0609	0.0679
D1	0.1044	0.0700
D2	-0.0151	0.0600
D3	-0.0717	0.0584
D4	-0.0133	0.0548
E1	0.0280	0.0600
E2	-0.0297	0.0600
E3	-0.3405	0.0974
E4	-0.1235	0.0670
F1	-0.1394	0.0600
F2	-0.6222	0.0600
F3	-0.2431	0.0851
F4	-0.1887	0.1129

BLOCK NO = (1A.11) NO OF EVENTS = 7

SUBARRAY MEAN STD. DEVIATION

R1	0.0685	0.0700
R2	0.0590	0.0724
R3	-0.0498	0.0799
R4	-0.0501	0.0700
C1	0.0872	0.0700
C2	0.0403	0.0422
C3	-0.0458	0.0374
C4	-0.0885	0.0700
D1	0.0585	0.0700
D2	-0.1099	0.0785
D3	-0.0923	0.0457
E1	-0.0580	0.0700
E2	-0.0781	0.0797
E3	-0.3869	0.0627
F1	-0.2886	0.0700
F2	-0.5753	0.0668
F3	-0.3034	0.0692

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BLOCK NO = (18.13) NO OF EVENTS = 1

SUBARRAY	MEAN	STD. DEVIATION
R1	-0.1733	
R2	0.0273	
R3	-0.0841	
R4	-0.1251	
C1	0.0930	
C2	0.0000	
C3	-0.0230	
C4	-0.0206	
D1	-0.1929	
D2	-0.2329	
D3	-0.0751	
D4	0.0000	
<hr/>		
F1	-0.3194	
F2	-0.1212	
F3	0.0000	
F4	-0.0035	
<hr/>		
F1	0.0000	
F2	-0.5911	
F3	-0.2079	
F4	-0.3055	

BLOCK NO = (18.14) NO OF EVENTS = 8

SUBARRAY	MEAN	STD. DEVIATION
R1	-0.1295	0.0402 ←
R2	0.0400	0.0660
R3	0.0077	0.0586
R4	-0.0011	0.0657
C1	-0.0154	0.0667
C2	-0.0254	0.0634
C3	0.0574	0.0611
C4	0.0166	0.0764
D1	-0.1820	0.1210
D2	-0.2169	0.1953
D3	-0.0953	0.0676
D4	0.0999	0.0729
<hr/>		
F1	-0.2509	0.1234
F2	-0.0480	0.0634
F3	-0.2132	0.2020
F4	0.0638	0.0765
<hr/>		
F1	-0.2288	0.2020
F2	-0.4055	0.1899
F3	-0.2195	0.0742
F4	-0.2254	0.0642

BLOCK NO = (18.15)

NO OF EVENTS = 4

SUBARRAY MEAN STD. DEVIATION

R1	-0.1049	0.0811
R2	-0.0170	0.0626
R3	0.0041	0.0312
R4	-0.0619	0.1007
C1	-0.0899	0.1061
C2	-0.0864	0.1282
C3	0.0399	0.0666
C4	0.0074	0.0315
D1	-0.1507	0.1215
D2	-0.2196	0.1607
D3	-0.0090	0.0389
D4	0.0210	0.0408
<hr/>		
F1	-0.1897	0.0822
F2	0.0293	0.0366
F3	-0.3177	0.2281
F4	0.1012	0.0460
<hr/>		
F1	-0.2110	0.1493
F2	-0.4194	0.3038
F3	-0.1367	0.1147
F4	-0.1901	0.1131

BLOCK NO = (18.16)

NO OF EVENTS = 2

SUBARRAY MEAN STD. DEVIATION

R1	-0.0010	0.0000
R2	0.0186	0.1131
R3	-0.0021	0.0000
R4	-0.0920	0.0068
C1	-0.0943	0.0111
C2	-0.0623	0.0000
C3	0.0844	0.0135
C4	-0.0593	0.0280
D1	-0.0406	0.0726
D2	-0.0962	0.0000
D3	-0.1630	0.0338
D4	-0.1011	0.0572
<hr/>		
F1	-0.3855	0.0255
F2	0.3302	0.0000
F3	-0.1047	0.0537
F4	-0.1454	0.0283
<hr/>		
F1	-0.1151	0.0356
F2	-0.0083	0.0416
F3	-0.0688	0.0062
F4	-0.3524	0.1896

BLOCK NO = (18.25)

NO OF EVENTS = 7

SUBARRAY	MEAN	STD. DEVIATION
R1	-0.0129	0.0570
R2	-0.0518	0.0765
R3	-0.0233	0.0415
R4	-0.0352	0.0820
C1	0.0284	0.0504
C2	-0.0274	0.0476
C3	-0.1545	0.1239
C4	-0.1082	0.1495
D1	0.0330	0.0647
D2	-0.2963	0.2373
D3	-0.2700	0.1778
D4	-0.1311	0.1014
<hr/>		
F1	0.1096	0.0580
F2	-0.2813	0.0664
F3	-0.5937	0.2851
F4	-0.7161	0.3295
<hr/>		
F1	0.0948	0.0429
F2	-0.6754	0.0461
F3	-0.8221	0.0678
F4	-0.4722	0.0819

BLOCK NO = (18.22)

NO OF EVENTS = 2

SUBARRAY	MEAN	STD. DEVIATION
R1	-0.0155	0.0041
R2	-0.1491	0.0017
R3	0.0155	0.0145
R4	0.0452	0.0395
C1	-0.1374	0.0054
C2	-0.1693	0.0060
C3	-0.1756	0.0090
C4	-0.0291	0.0576
D1	-0.0741	0.0069
D2	-0.4175	0.0000
D3	-0.1984	0.0650
D4	-0.0538	0.0214
<hr/>		
F1	-0.1138	0.0616
F2	-0.4115	0.0568
F3	-0.5878	0.0632
F4	-0.5369	0.1158
<hr/>		
F1	-0.3325	0.0531
F2	-0.8623	0.0000
F3	-0.8522	0.0280
F4	-0.5406	0.0036

BLOCK NO = 118.297 NO OF

SUBARRAY MEAN STD. DEVIATION

B1	-0.0668	0.0175
B2	-0.1232	0.0461
B3	0.0592	0.0293
B4	-0.0064	0.0349
C1	-0.0979	0.0341
C2	-0.2036	0.0317
C3	-0.1980	0.0536
C4	-0.0214	0.0211
D1	-0.1510	0.0620
D2	-0.4556	0.0384
D3	-0.1194	0.0341
D4	-0.0911	0.0579
E1	-0.1993	0.0598
E2	-0.4877	0.0290
F3	-0.4940	0.2874
F4	-0.4149	0.0339
F1	-0.3019	0.1889
F2	-0.8694	0.0464
F3	-0.7497	0.0454
F4	-0.5485	0.3177

BLOCK NO = 118.321 NO OF EVENTS = 2

SUBARRAY MEAN STD. DEVIATION

B1	-0.1383	0.0499
B2	-0.2975	0.0498
B3	0.0166	0.0496
B4	0.0345	0.0288
C1	-0.1078	0.0343
C2	-0.3319	0.1420
C3	-0.3336	0.0351
C4	0.0478	0.0351
D1	-0.2301	0.0351
D2	-0.6504	0.0061
D3	-0.0730	0.0002
D4	-0.0730	0.0002
E1	-0.1982	0.0000
F2	-0.5870	0.0000
F3	-0.6179	0.0202
F4	-0.2921	0.0000
F1	-0.2969	0.0000
F2	-0.7813	0.0109
F3	-0.5741	0.0022
F4	-0.5547	0.0000

BLOCK NO = (19.01) NO OF EVENTS = 5

SUBARRAY	MEAN	STD. DEVIATION
R1	0.0000	
R2	0.0000	
R3	0.0000	
R4	0.0154	
C1	0.1094	
C2	0.1880	
C3	0.0288	
C4	-0.0413	
D1	0.2149	
D2	-0.0260	
D3	-0.0113	
D4	0.0317	
<hr/>		
F1	0.0733	
F2	0.0010	
F3	0.0000	
F4	-0.0522	
<hr/>		
F1	0.0000	
F2	-0.5358	
F3	0.0000	
F4	-0.0227	

BLOCK NO = (19.14) NO OF EVENTS = 5

SUBARRAY	MEAN	STD. DEVIATION
R1	-0.1263	0.0000
R2	0.0242	0.0000
R3	-0.0035	0.0000
R4	-0.0754	0.1102
C1	-0.0260	0.0882
C2	-0.0889	0.0604
C3	0.0577	0.0674
C4	-0.0205	0.0361
D1	-0.1614	0.1054
D2	-0.2083	0.3680
D3	-0.0952	0.0730
D4	0.0913	0.0909
<hr/>		
E1	-0.2062	0.1817
F2	-0.0523	0.0571
F3	-0.3835	0.6662
F4	0.0610	0.0610
<hr/>		
F1	-0.2672	0.1579
F2	-0.4211	0.0313
F3	-0.5122	0.0423
F4	-0.2512	0.0572

BLOCK NO = (19.19) NO OF EVENTS = 5

SUBARRAY MEAN STD. DEVIATION

B1	-0.1254	0.0275
B2	-0.0074	0.0591
B3	-0.0155	0.0468
B4	-0.0803	0.0724
C1	-0.1285	0.0325
C2	-0.1196	0.0831
C3	-0.0154	0.0594
C4	-0.0421	0.0341
D1	-0.1732	0.0286
D2	-0.1991	0.1738
D3	-0.1330	0.0299
D4	0.0856	0.0440
<hr/>		
F1	-0.2222	0.0477
F2	0.0346	0.1823
F3	-0.3775	0.1768
F4	0.1161	0.0813
<hr/>		
F1	-0.1855	0.0712
F2	-0.2574	0.1209
F3	-0.2303	0.0443
F4	-0.1422	0.1881

BLOCK NO = (19.30) NO OF EVENTS = 1

SUBARRAY MEAN STD. DEVIATION

B1	-0.0066	
B2	-0.1710	
B3	0.1029	
B4	0.1042	
C1	0.0276	
C2	-0.1842	
C3	-0.2615	
C4	0.1399	
D1	-0.0780	
D2	-0.4827	
D3	-0.0906	
<hr/>		
F1	-0.5507	
F2	-0.6100	
<hr/>		
F1	-0.2987	
F2	-0.8940	
F3	-0.8066	

BLOCK NO = (19.31) NO OF EVENTS = 8

SUBARRAY	MEAN	STD. DEVIATION
R1	-0.0869	0.0768
R2	-0.2714	0.1723
R3	0.0487	0.0237
R4	0.0711	0.0437
C1	-0.0304	0.0444
C2	-0.3336	0.2120
C3	-0.2042	0.2724
C4	0.1123	0.0670
D1	-0.1756	0.1055
D2	-0.5605	0.6486
D3	-0.1093	0.0714
D4	-0.0428	0.0520
<hr/>		
F1	-0.1831	0.0987
F2	-0.4933	0.2152
F3	-0.5477	0.2300
F4	-0.2547	0.1124
<hr/>		
F1	-0.3022	0.0361
F2	-0.7709	0.4979
F3	-0.5879	0.2532
F4	-0.4306	0.0406

BLOCK NO = (19.32) NO OF EVENTS = 2

SUBARRAY	MEAN	STD. DEVIATION
R1	-0.1161	0.0424
R2	-0.2363	0.0424
R3	0.0331	0.0424
R4	0.0567	0.0636
C1	-0.0110	0.0000
C2	-0.3325	0.0000
C3	-0.3364	0.0000
C4	0.1146	0.0636
D1	-0.1892	0.0141
D2	-0.5754	0.0000
D3	-0.1351	0.0636
D4	0.0949	0.0000
<hr/>		
F1	-0.3330	0.0000
F2	-0.5195	0.0354
F3	0.0000	-0.0000
F4	-0.1877	0.0000
<hr/>		
F1	-0.1567	0.0000
F2	-0.8058	0.0000
F3	-0.4723	0.0495
F4	-0.4152	0.0495

BLOCK NO = (20.15)

NO OF EVENTS = 9

SUBARRAY	MEAN	STD. DEVIATION
B1	-0.1054	0.0696
B2	-0.0082	0.0669
B3	-0.0590	0.0422
B4	-0.1263	0.0878
C1	-0.1085	0.0635
C2	-0.0664	0.0700
C3	-0.0633	0.0199
C4	-0.1099	0.1226
D1	-0.0693	0.0888
D2	-0.2260	0.1407
D3	-0.1537	0.0719
D4	0.0348	0.0473
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F1	-0.1540	0.0841
F2	0.0171	0.0337
F3	-0.3764	0.0449
F4	-0.0351	0.0480
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F1	0.0017	0.1015
F2	-0.3735	0.2228
F3	-0.2716	0.0579
F4	-0.3333	0.0951

BLOCK NO = (20.16)

NO OF EVENTS = 3

SUBARRAY	MEAN	STD. DEVIATION
B1	-0.1407	0.0409
B2	-0.0336	0.0389
B3	-0.0534	0.0488
B4	-0.1199	0.0250
C1	-0.1397	0.0334
C2	-0.1188	0.1191
C3	-0.0751	0.0251
C4	-0.1160	0.0088
D1	-0.1604	0.0279
D2	-0.2446	0.0347
D3	-0.2180	0.2201
D4	0.0078	0.0378
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F1	-0.2153	0.0388
F2	-0.0307	0.0380
F3	-0.3397	0.0159
F4	-0.0379	0.0378
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F1	-0.0685	0.0486
F2	-0.2973	0.1349
F3	-0.2535	0.0212
F4	-0.3844	0.0335

BLOCK NO = (20.31) NO OF EVENTS = 1

SUBARRAY	MEAN	STD. DEVIATION
B1	-0.1079	
B2	-0.2876	
B3	0.0000	
B4	-0.0058	
C1	-0.0908	
C2	-0.2380	
C3	-0.2069	
C4	0.0121	
D1	-0.2482	
D2	-0.5155	
D3	0.0000	
D4	-0.0432	
<hr/>		
F1	-0.2565	
F2	-0.5506	
F3	-0.7097	
F4	-0.4127	
<hr/>		
F1	-0.2413	
F2	-0.8242	
F3	-0.6222	
F4	-0.4697	

BLOCK NO = (21.16) NO OF EVENTS = 7

SUBARRAY	MEAN	STD. DEVIATION
B1	-0.0713	0.0694
B2	-0.0166	0.0657
B3	0.0132	0.0552
B4	-0.0799	0.0896
C1	-0.0894	0.0903
C2	-0.0014	0.0502
C3	-0.0527	0.0209
C4	-0.1384	0.1503
D1	-0.0447	0.0505
D2	-0.1984	0.0742
D3	-0.1537	0.0756
D4	-0.0026	0.0517
<hr/>		
F1	-0.1006	0.0561
F2	-0.0477	0.0406
F3	-0.2957	0.3005
F4	-0.1064	0.0919
<hr/>		
F1	-0.0094	0.0463
F2	-0.3430	0.2491
F3	-0.2669	0.0434
F4	-0.3410	0.1652

BLOCK NO = (21.17)

NO OF EVENTS = 3

SUBARRAY	MEAN	STD. DEVIATION
R1	-0.1062	0.0158
R2	-0.0363	0.0360
R3	-0.0225	0.0193
R4	-0.1620	0.0673
C1	-0.0847	0.1021
C2	-0.0228	0.0346
C3	-0.0903	0.0182
C4	-0.1503	0.0086
D1	0.0098	0.0297
D2	-0.1401	0.1460
D3	-0.2137	0.0455
D4	-0.1357	0.0562
F1	-0.1621	0.0427
F2	-0.1016	0.0474
F3	-0.3716	0.0424
F4	-0.2099	0.0100
F1	0.1074	0.0567
F2	-0.3678	0.0201
F3	-0.4086	0.0114
F4	-0.4904	0.0499

BLOCK NO = (21.18)

NO OF EVENTS = 5

SUBARRAY	MEAN	STD. DEVIATION
R1	-0.0580	0.1051
R2	-0.0610	0.0573
R3	-0.0372	0.0754
R4	-0.1810	0.1100
C1	-0.1153	0.0964
C2	-0.0711	0.1387
C3	-0.0667	0.0858
C4	-0.1580	0.1060
D1	-0.0506	0.0234
D2	-0.1620	0.1329
D3	-0.2221	0.1370
D4	-0.1249	0.1374
F1	-0.1215	0.0839
F2	-0.0415	0.0654
F3	-0.2987	0.0479
F4	-0.1482	0.1266
F1	0.1309	0.0921
F2	-0.2823	0.1849
F3	-0.3731	0.0427
F4	-0.4552	0.2690

BLOCK NO = (22.16)

NO OF EVENTS = 2

SUBARRAY	MEAN	STD. DEVIATION
R1	-0.1513	0.0887
R2	-0.0679	0.0566
R3	-0.0521	0.0650
R4	0.0000	-0.0000
C1	-0.1370	0.0000
C2	-0.1148	0.0282
C3	-0.0735	0.0492
C4	-0.1588	0.0000
D1	-0.0811	0.0000
D2	0.0000	-0.0000
D3	-0.1347	0.0852
D4	-0.0319	0.0000
<hr/>		
F1	-0.0651	0.0000
F2	-0.0939	0.1118
F3	-0.2483	0.0000
F4	-0.1189	0.0000
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F1	0.0260	0.0952
F2	-0.4263	0.1184
F3	-0.4440	0.0141
F4	-0.3146	0.0230

BLOCK NO = (22.17)

NO OF EVENTS = 1

SUBARRAY	MEAN	STD. DEVIATION
R1	0.0000	
R2	-0.0451	
R3	-0.0513	
R4	-0.0844	
C1	-0.1700	
C2	-0.0656	
C3	-0.0521	
C4	-0.1723	
D1	-0.0793	
D2	-0.1337	
D3	-0.2800	
D4	-0.1187	
<hr/>		
F1	-0.1064	
F2	-0.0586	
F3	-0.3613	
F4	-0.2570	
<hr/>		
F1	0.1152	
F2	-0.2908	
F3	-0.4423	
F4	-0.3908	

BLOCK NO = (22.38)

NO

SUBARRAY	MEAN	STD. DEVIATION
R1	0.0000	
R2	-0.2183	
R3	-0.1194	
R4	0.0000	
C1	0.0000	
C2	-0.1216	
C3	-0.3567	
C4	0.1467	
D1	0.0000	
D2	-0.4021	
D3	0.0000	
D4	0.0000	
F1	0.1354	
F2	-0.2941	
F3	-0.5145	
F4	0.0000	
F1	0.0000	
F2	-0.8778	
F3	0.0000	
F4	0.0000	

BLOCK NO = (23. 5)

NO OF EVENTS = 1

SUBARRAY	MEAN	STD. DEVIATION
R1	0.0000	
R2	0.0000	
R3	0.0000	
R4	0.0000	
C1	0.0000	
C2	-0.3076	
C3	0.0000	
C4	0.0000	
D1	0.0000	
D2	0.0000	
D3	0.5873	
D4	-0.2933	
F1	0.0000	
F2	0.0000	
F3	-0.1781	
F4	0.4901	
F1	0.0000	
F2	0.0000	
F3	0.0681	
F4	0.0698	

ADDITIONAL INFORMATION

BLOCK NO = (23.15)

NO OF EVENTS = 1

SUBARRAY	MEAN	STD. DEVIATION
R1	0.0000	
R2	0.0000	
R3	0.0000	
R4	0.0000	
C1	0.0000	
C2	0.0000	
C3	-0.0924	
C4	-0.1435	
D1	-0.1290	
D2	-0.3527	
D3	-0.2714	
D4	-0.1943	
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F1	0.0000	
F2	0.0000	
F3	-0.6156	
F4	-0.1070	
<hr/>		
F1	0.0677	
F2	-0.4749	
F3	0.0000	
F4	-0.2811	

BLOCK NO = (23.16)

NO OF EVENTS = 1

SUBARRAY	MEAN	STD. DEVIATION
R1	-0.0341	
R2	-0.0778	
R3	0.0000	
R4	-0.1169	
C1	-0.0342	
C2	-0.1227	
C3	-0.1162	
C4	0.0000	
D1	-0.0827	
D2	-0.2625	
D3	-0.2139	
D4	-0.1514	
<hr/>		
F1	-0.2274	
F2	-0.0745	
F3	-0.4677	
F4	-0.1226	
<hr/>		
F1	-0.0200	
F2	-0.3736	
F3	0.0000	
F4	-0.2746	

BLOCK NO = (23.39)

NO OF EVENTS = 2

SUBARRAY	MEAN	STD. DEVIATION
B1	-0.0405	0.0000
B2	-0.2114	0.0704
B3	-0.0829	0.1222
B4	0.1299	0.0299
C1	0.0545	0.1082
C2	-0.1718	0.0216
C3	-0.3722	0.0300
C4	0.1681	0.0047
D1	-0.0250	0.0580
D2	-0.3616	0.0753
D3	-0.2412	0.0272
D4	0.0346	0.0047
E1	0.0411	0.0343
E2	-0.1943	0.0946
E3	-0.4598	0.0468
E4	-0.3824	0.0515
F1	0.1771	0.0000
F2	-0.7415	0.0189
F3	-0.6879	0.0041
F4	-0.2993	0.0060

BLOCK NO = (24.15)

NO OF EVENTS = 3

SUBARRAY	MEAN	STD. DEVIATION
B1	-0.1928	0.0686
B2	-0.1064	0.1064
B3	-0.0597	0.0357
B4	-0.1933	0.0595
C1	-0.1712	0.0658
C2	-0.0832	0.1017
C3	-0.1407	0.0602
C4	-0.1357	0.0607
D1	-0.0536	0.0492
D2	-0.2367	0.2410
D3	-0.2109	0.0248
D4	-0.1242	0.0550
E1	-0.0758	0.1548
E2	-0.1768	0.0464
E3	-0.5901	0.0709
E4	-0.2508	0.0555
F1	0.0433	0.0000
F2	-0.5057	0.0441
F3	-0.4674	0.1226
F4	-0.3195	0.0546

BLOCK NO = (24.16) NO OF EVENTS = 1

SUBARRAY	MEAN	STD. DEVIATION
R1	-0.1726	
R2	-0.1395	
R3	-0.1122	
R4	-0.1381	
C1	-0.1208	
C2	-0.1313	
C3	-0.1748	
C4	-0.1872	
D1	-0.0506	
D2	0.0000	
D3	-0.1974	
D4	0.0000	
<hr/>		
F1	-0.2388	
F2	-0.1012	
F3	-0.4572	
F4	-0.2237	
<hr/>		
F1	0.0588	
F2	-0.4554	
F3	-0.4200	
F4	-0.2207	

BLOCK NO = (25.15) NO OF EVENTS = 2

SUBARRAY	MEAN	STD. DEVIATION
R1	-0.1798	0.0000
R2	-0.0727	0.0642
R3	-0.0244	0.0000
R4	-0.1198	0.0133
C1	-0.1754	0.0467
C2	-0.1156	0.0000
C3	-0.1556	0.0797
C4	-0.1334	0.0812
D1	-0.1364	0.1163
D2	-0.2841	0.0868
D3	-0.2361	0.0418
D4	-0.2238	0.0301
<hr/>		
F1	-0.1923	0.0581
F2	-0.1170	0.1757
F3	-0.3305	0.0000
F4	-0.2370	0.0586
<hr/>		
F1	0.0373	0.0000
F2	-0.2730	0.1075
F3	-0.2763	0.0786
F4	-0.4969	0.0415

BLOCK NO = 125.1

NO OF EVENTS = 1

SUBARRAY MEAN STD.DEVIATION

R1	-0.0747
R2	-0.0455
R3	0.0353
R4	0.0000
C1	0.0000
C2	0.0000
C3	0.0000
C4	0.0000
D1	-0.0708
D2	0.0000
D3	-0.2046
D4	0.0000
F1	0.0000
F2	0.0000
F3	-0.3715
F4	-0.1838
F1	0.0000
F2	0.0000
F3	-0.3547
F4	0.0000

BLOCK NO = 129.15

NO OF EVENTS = 1

SUBARRAY MEAN STD.DEVIATION

R1	-0.0854
R2	-0.1208
R3	-0.0687
R4	-0.1147
C1	-0.1901
C2	-0.1757
C3	-0.1715
C4	-0.0909
D1	-0.0979
D2	-0.3041
D3	-0.1790
D4	-0.3333
F1	-0.2498
F2	-0.2332
F3	-0.2154
F4	-0.1417
F1	-0.1252
F2	-0.3432
F3	0.0074
F4	-0.7850

BLOCK NO = (30.35)

NO OF EVENTS = 1

SUBARRAY	MEAN	STD. DEVIATION
R1	0.0000	
R2	0.0000	
R3	0.0000	
R4	0.1182	
C1	0.1654	
C2	-0.0255	
C3	-0.2714	
C4	0.2425	
D1	0.1464	
D2	-0.2209	
D3	0.0000	
D4	0.0000	
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F1	0.1617	
F2	-0.1402	
F3	-0.3816	
F4	-0.1445	
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F1	0.1454	
F2	0.0000	
F3	-0.6358	
F4	-0.2631	

BLOCK NO = (21.15)

NO OF EVENTS = 2

SUBARRAY	MEAN	STD. DEVIATION
R1	-0.0840	0.0994
R2	-0.1518	0.0153
R3	-0.0222	0.0187
R4	-0.0502	0.0421
C1	-0.1572	0.0532
C2	-0.1315	0.0000
C3	-0.1802	0.0257
C4	-0.0670	0.0209
D1	-0.1204	0.0000
D2	-0.2904	0.0000
D3	-0.1480	0.1629
D4	-0.3395	0.0000
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F1	-0.3999	0.0111
F2	-0.1903	0.0785
F3	-0.2134	0.2306
F4	-0.1125	0.1162
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F1	-0.2898	0.0000
F2	-0.4254	0.0000
F3	-0.1528	0.0895
F4	-0.0142	0.0236

SUBARRAY MEAN STD. DEVIATION

B3 0.0000
B4 0.0000

C3 -0.1719
C4 0.2069

D3 0.0000
D4 -0.0096

E3 -0.3833
E4 -0.0431

F3 -0.5426
F4 -0.3222

BLOCK NO = (31.36) NO OF EVENTS = 1

SUBARRAY MEAN STD. DEVIATION

R2 -0.0320
R3 0.1058

C2 -0.0752
C3 -0.1969

D2 -0.1500
D3 0.0000

F2 -0.3067
F3 -0.3217

F2 -0.5835
F3 -0.5795

BLOCK NO = (32,35)

NO OF EVENTS = 1

SUBARRAY	MEAN	STD. DEVIATION
B1	0.0159	
B2	-0.1068	
B3	0.0183	
B4	0.1753	
C1	0.1375	
C2	-0.0535	
C3	-0.1755	
C4	0.2555	
D1	0.0024	
D2	-0.2863	
D3	-0.1516	
D4	0.1317	
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F1	0.2184	
F2	-0.2512	
F3	-0.3962	
F4	0.0539	
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F1	-0.0229	
F2	-0.5934	
F3	-0.5375	
F4	-0.2195	

BLOCK NO = (33,38)

NO OF EVENTS = 1

SUBARRAY	MEAN	STD. DEVIATION
B1	0.0000	
B2	0.0000	
B3	0.0000	
B4	0.0000	
C1	0.1546	
C2	-0.1574	
C3	-0.3766	
C4	0.3443	
D1	0.0797	
D2	-0.4239	
D3	0.0005	
D4	0.4066	
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F1	0.2303	
F2	-0.3217	
F3	-0.5440	
F4	0.2102	
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F1	0.1421	
F2	-0.6889	
F3	-0.7430	
F4	-0.2797	

BLOCK NO = 133.991 NO OF EVENTS = 1

SUBARRAY MEAN STD. DEVIATION

R1 0.0730
R2 0.0000
R3 0.0715
R4 0.2174
C1 0.2785
C2 0.0144
C3 -0.2203
C4 0.3038
D1 0.1447
D2 0.0000
D3 0.0406
D4 0.6089
F1 0.2445
F2 -0.0592
F3 0.0000
F4 0.2615
F1 0.0563
F2 -0.4597
F3 -0.5671
F4 -0.2032

BLOCK NO = 134.441 NO OF EVENTS = 1

SUBARRAY MEAN STD. DEVIATION

R1 0.3280
R2 0.0000
R3 0.0000
R4 0.2705
C1 0.0000
C2 0.3014
C3 0.0000
C4 0.2753
D1 0.0000
D2 0.0000
D3 -0.0139
D4 0.5784
F1 0.0000
F2 0.4375
F3 -0.2470
F4 0.3985
F1 1.0326
F2 -0.2741
F3 -0.4831
F4 0.0900

BLOCK NO = (35.15) NO OF EVENTS = 16

SUBARRAY	MEAN	STD. DEVIATION
R1	-0.0237	0.0657
R2	-0.2166	0.2714
R3	-0.0675	0.0916
R4	0.072	0.0705
C1	-0.0067	0.0567
C2	-0.2890	0.1538
C3	-0.1731	0.0410
C4	0.0739	0.0580
D1	-0.0662	0.0559
D2	-0.3743	0.1124
D3	-0.1702	0.0921
D4	-0.2217	0.1591
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F1	-0.3237	0.1598
F2	-0.5136	0.2605
F3	-0.4535	0.2788
F4	-0.0549	0.0556
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F1	-0.1360	0.0643
F2	-0.6865	0.1952
F3	-0.2443	0.1448
F4	-0.7830	0.2189

BLOCK NO = (35.16) NO OF EVENTS = 16

SUBARRAY	MEAN	STD. DEVIATION
R1	-0.0513	0.0828
R2	-0.2635	0.1130
R3	-0.0926	0.0567
R4	0.0802	0.0589
C1	0.0075	0.0461
C2	-0.3097	0.1247
C3	-0.1997	0.0535
C4	0.0408	0.0403
D1	-0.0452	0.0493
D2	-0.3710	0.1106
D3	-0.1878	0.0904
D4	-0.2027	0.1353
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F1	-0.2405	0.0895
F2	-0.4521	0.1915
F3	-0.4585	0.1954
F4	-0.0315	0.0831
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F1	-0.0815	0.0985
F2	-0.6533	0.0658
F3	-0.2445	0.1221
F4	-0.7699	0.2124

BLOCK NO = 136.81

SUBARRAY MEAN STD. DEVIATION

R1	-0.0894	0.0767
R2	-0.2999	0.0733
R3	-0.0894	0.0767
R4	0.0316	0.0634
C1	0.0024	0.0537
C2	-0.5092	0.0185
C3	-0.2940	0.0148
C4	0.0676	0.0371
D1	-0.0703	0.0493
D2	-0.4514	0.0000
D3	-0.2272	0.0153
D4	-0.2003	0.0475
E1	-0.2623	0.0671
E2	-0.4989	0.0000
E3	-0.5665	0.0279
E4	-0.0060	0.0688
F1	-0.1164	0.0658
F2	-0.6319	0.0000
F3	-0.3523	0.0658
F4	-0.8073	0.8084

BLOCK NO = 137.401 NO OF EVENTS = 1

SUBARRAY MEAN STD. DEVIATION

R1	0.1599	0.0000
R2	-0.1421	0.0000
R3	0.0012	0.0000
R4	0.0000	0.0000
C1	0.2944	0.0000
C2	0.1098	0.0000
C3	-0.1493	0.0000
C4	0.3602	0.0000
D1	0.3500	0.0000
D2	0.0000	0.0000
D3	0.0300	0.0000
E1	0.3900	0.0000
E2	-0.0597	0.0000
E3	-0.1944	0.0000
E4	0.0000	0.0000
F1	0.2487	0.0000
F2	-0.5860	0.0000
F3	-0.5358	0.0000

BLOCK NO = (38.40)

NO OF EVENTS = 2

SUBARRAY	MEAN	STD. DEVIATION
R1	0.0468	0.0031
R2	-0.1561	0.0546
R3	0.0075	0.0499
R4	0.2042	0.0000
C1	0.2643	0.0057
C2	-0.0783	0.1420
C3	-0.1823	0.0738
C4	0.2732	0.0051
D1	0.2725	0.0000
D2	-0.2751	0.1057
D3	-0.0309	0.0930
D4	0.6218	0.0340
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F1	0.3427	0.0077
F2	-0.1740	0.0027
F3	-0.1539	0.0000
F4	0.3158	0.0641
<hr/>		
F1	0.2457	0.0309
F2	-0.4428	0.0000
F3	-0.6109	0.0000
F4	0.2187	0.1859

BLOCK NO = (39.39)

NO OF EVENTS = 2

SUBARRAY	MEAN	STD. DEVIATION
B1	0.0939	0.0000
B2	-0.1821	0.0421
B3	-0.1741	0.0645
B4	0.1513	0.0481
C1	0.2842	0.0189
C2	0.0040	0.0025
C3	-0.2463	0.0126
C4	0.1391	0.0864
D1	0.2860	0.0500
D2	-0.2847	0.0000
D3	-0.1624	0.0000
D4	0.7334	0.0000
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F1	0.7094	0.0495
F2	-0.1011	0.0594
F3	-0.4435	0.0000
F4	0.1993	0.0020
<hr/>		
F1	0.8189	0.0645
F2	-0.2914	0.0000
F3	0.0154	0.0000
F4	0.2771	0.0042

BLOCK NO = (39.30) NO OF EVENTS = 5

SUBARRAY MEAN STD. DEVIATION

B1 0.1397
B2 -0.0704
B3 0.0225
B4 0.2120
C1 0.3338
C2 0.0236
C3 -0.1215
C4 0.2884
D1 0.3240
D2 -0.1001
D3 -0.0239
D4 0.7177
E1 0.5885
E2 -0.0366
E3 -0.3245
E4 0.2798
F1 0.0000
F2 -0.4437
F3 -0.6723
F4 0.3682

BLOCK NO = (40.30) NO OF EVENTS = 5

SUBARRAY MEAN STD. DEVIATION

B1 0.0089
B2 -0.1643
B3 0.0041
B4 0.2169
C1 0.2754
C2 -0.0973
C3 -0.1623
C4 0.2070
D1 0.2346
D2 -0.2858
D3 -0.0419
D4 0.6545
E1 0.2783
E2 -0.4534
E3 0.0015
E4 0.3235
F1 0.3329
F2 -0.1531
F3 0.0563
F4 0.0000

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BLOCK NO = (40.31)

NO OF EVENTS = 2

SUBARRAY	MEAN	STD. DEVIATION
R1	0.0589	0.0437
R2	-0.0680	0.1061
R3	0.0337	0.0441
R4	0.2341	0.0522
C1	0.2863	0.0034
C2	-0.0588	0.1473
C3	-0.2055	0.0788
C4	0.2315	0.0057
D1	0.2122	0.0534
D2	-0.3011	0.0000
D3	0.0051	0.0026
D4	0.4655	0.0300
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F1	0.4067	0.0000
F2	-0.3786	0.0536
F3	0.0173	0.0521
F4	0.2977	0.0486
<hr/>		
F1	0.2871	0.0747
F2	-0.1831	0.0393
F3	0.0488	0.0883
F4	0.0535	0.0160

BLOCK NO = (40.40)

NO OF EVENTS = 2

SUBARRAY	MEAN	STD. DEVIATION
R1	0.1090	0.0329
R2	-0.0445	0.0531
R3	-0.0451	0.0111
R4	0.2571	0.0102
C1	0.3443	0.0137
C2	0.0227	0.0588
C3	-0.1590	0.0000
C4	0.2936	0.0137
D1	0.3272	0.0004
D2	-0.2113	0.0021
D3	-0.0370	0.0201
D4	0.8130	0.0000
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F1	0.6694	0.0000
F2	-0.1093	0.0000
F3	-0.2488	0.0053
F4	0.2895	0.0000
<hr/>		
F1	0.0000	-0.0000
F2	-0.4490	0.0206
F3	-0.4358	0.0093
F4	0.5794	0.0300

BLOCK NO = (41,28)

NO OF EVENTS = 1

SUBARRAY MEAN STD. DEVIATION

R1 -0.0129

R2 -0.1413

R3 -0.0157

R4 0.1864

C1 0.1567

C2 -0.1227

C3 0.0000

C4 0.2025

D1 0.1325

D2 -0.2795

D3 -0.0417

D4 0.4110

F1 0.0000

F2 0.0000

F3 0.0000

F4 0.2892

F1 0.0000

F2 -0.1534

F3 0.1127

F4 0.0000

BLOCK NO = (41,29)

NO OF EVENTS = 2

SUBARRAY MEAN STD. DEVIATION

R1 -0.0270

R2 -0.1554

R3 -0.0199

R4 0.1528

C1 0.1799

C2 -0.1109

C3 -0.1758

C4 0.1869

D1 0.1911

D2 -0.2876

D3 -0.0336

D4 0.4705

F1 0.1880

F2 -0.4130

F3 -0.0889

F4 0.2453

F1 0.2830

F2 -0.1530

F3 0.0367

F4 -0.1110

BLOCK NO = (41.30)

NO OF EVENTS = 7

SUBARRAY	MEAN	STD. DEVIATION
B1	0.0125	0.0888
B2	-0.1432	0.1457
B3	-0.0440	0.0535
B4	0.2399	0.2620
C1	0.2157	0.1641
C2	-0.1188	0.0929
C3	-0.1938	0.1547
C4	0.2218	0.1712
D1	0.1663	0.0617
D2	-0.2793	0.0702
D3	-0.0253	0.0799
D4	0.3754	0.8400
<hr/>		
F1	0.2576	0.1964
F2	-0.3874	0.0229
F3	-0.0257	0.1119
F4	0.2957	0.0457
<hr/>		
F1	0.2311	0.2454
F2	-0.1520	0.0449
F3	0.0240	0.0885
F4	-0.0903	0.1126

BLOCK NO = (41.31)

NO OF EVENTS = 7

SUBARRAY	MEAN	STD. DEVIATION
B1	0.0208	0.0422
B2	-0.1945	0.0928
B3	-0.0765	0.0800
B4	0.1786	0.0855
C1	0.2560	0.1076
C2	-0.1086	0.0870
C3	-0.1902	0.1389
C4	0.2306	0.1705
D1	0.1582	0.0785
D2	-0.3220	0.2324
D3	0.0309	0.0365
D4	0.4400	0.2070
<hr/>		
F1	0.4120	0.0717
F2	-0.4111	0.1911
F3	0.0514	0.0490
F4	0.3757	0.1035
<hr/>		
F1	0.3212	0.1776
F2	-0.1500	0.0792
F3	0.0438	0.0530
F4	-0.0315	0.1073

BLOCK NO = (41.32)

NO OF EV

SUBARRAY MEAN STD. DEVIATION

SUBARRAY	MEAN	STD. DEVIATION
B1	-0.0090	0.0392
B2	-0.1294	0.2694
B3	0.0171	0.0369
B4	0.2105	0.2979
C1	0.2887	0.4153
C2	-0.1385	0.1960
C3	-0.2185	0.3091
C4	0.2605	0.1866
D1	0.2247	0.1793
D2	-0.3839	0.5429
D3	0.0315	0.0853
D4	0.5590	0.4058
E1	0.4985	0.0745
E2	-0.3162	0.2350
F1	0.1130	0.0459
F4	0.4042	0.0899
F1	0.9830	0.2900
F2	-0.1372	0.0286
F3	0.1284	0.1004
F4	0.0337	0.0383

BLOCK NO = (42.31)

NO OF EVENTS = 2

SUBARRAY MEAN STD. DEVIATION

SUBARRAY	MEAN	STD. DEVIATION
B1	0.0513	0.0000
B2	-0.1366	0.0000
B3	0.1112	0.0000
B4	0.2593	0.0000
C1	0.3372	0.0000
C2	-0.0354	0.0505
C3	-0.0601	0.0848
C4	0.2896	0.0000
D1	0.2282	0.0000
D2	-0.3045	0.0363
D3	0.0754	0.0115
D4	0.5530	0.0000
E1	0.4173	0.1162
E2	-0.4869	0.0200
E3	0.0868	0.0136
E4	0.3159	0.0000
F1	0.9651	0.0000
F2	-0.1685	0.0241
F3	0.0915	0.0190
F4	0.0000	0.0000

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BLOCK NO = (42.32) NO OF EVENTS = 17

SUBARRAY	MEAN	STD. DEVIATION
B1	0.0131	0.0652
B2	-0.1705	0.1792
B3	0.0124	0.0709
B4	0.2353	0.2040
C1	0.3143	0.1717
C2	-0.0690	0.0823
C3	-0.1365	0.1047
C4	0.3004	0.1025
D1	0.1753	0.0872
D2	-0.2925	0.2290
D3	0.1380	0.1084
D4	0.6248	0.3120
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F1	0.5805	0.2428
F2	-0.3240	0.1415
F3	0.1147	0.0932
F4	0.4399	0.1419
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F1	0.4312	0.1989
F2	-0.1430	0.2133
F3	0.0880	0.0752
F4	0.1087	0.1542

BLOCK NO = (43.24) NO OF EVENTS = 1

SUBARRAY	MEAN	STD. DEVIATION
B1	0.0430	
B2	-0.2024	
B3	0.0507	
B4	0.3011	
C1	0.3395	
C2	0.0000	
C3	-0.1407	
C4	0.2243	
D1	0.1128	
D2	0.0000	
D3	-0.1539	
D4	0.0000	
<hr/>		
F1	0.4600	
F2	-0.4504	
F3	-0.2499	
F4	0.2171	
<hr/>		
F1	0.0000	
F2	-0.4421	
F3	-0.5458	
F4	-0.0230	

BLOCK NO = (43.32)

NO OF EVENTS = 9

SUBARRAY	MEAN	STD. DEVIATION
R1	-0.0180	0.0672
R2	-0.0936	0.1046
R3	0.0685	0.0576
R4	0.2098	0.0819
C1	0.2719	0.0639
C2	-0.1010	0.0482
C3	-0.1023	0.0228
C4	0.3312	0.0380
D1	0.1563	0.0547
D2	-0.1883	0.2624
D3	0.1899	0.0483
D4	0.7284	0.2810
<hr/>		
F1	0.7864	0.0463
F2	-0.3135	0.0504
F3	-0.0205	0.0593
F4	0.5815	0.0468
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F1	0.6735	0.0529
F2	-0.2027	0.1522
F3	-0.0140	0.0642
F4	0.4305	0.0678

BLOCK NO = (43.37)

NO OF EVENTS = 1

SUBARRAY	MEAN	STD. DEVIATION
R1	-0.0712	
R2	-0.0690	
R3	0.0463	
R4	0.0000	
C1	0.3254	
C2	0.0319	
C3	-0.0787	
C4	0.2680	
D1	0.2689	
D2	0.0000	
D3	0.2095	
D4	0.3719	
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F1	0.8483	
F2	-0.2473	
F3	0.1703	
F4	0.4192	
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F1	0.0000	
F2	-0.0701	
F3	-0.0176	
F4	0.8479	

BLOCK NO = (44.231) NO OF EVENTS = 2

SUBARRAY	MEAN	STD. DEVIATION
R1	0.0478	0.0078
R2	-0.0572	0.0000
R3	-0.0335	0.0659
R4	0.2497	0.1795
C1	0.3336	0.0665
C2	-0.0451	0.0076
C3	-0.0956	0.0598
C4	0.1308	0.0155
D1	0.1996	0.0132
D2	-0.2191	0.0032
D3	-0.1796	0.0270
D4	0.4113	0.0082
<hr/>		
F1	0.6517	0.1429
F2	0.3395	0.0622
F3	-0.2978	0.0268
F4	0.1349	0.0283
<hr/>		
F1	0.7450	0.0000
F2	-0.3123	0.0000
F3	-0.5222	0.1019
F4	0.0413	0.0000

BLOCK NO = (44.24) NO OF EVENTS = 2

SUBARRAY	MEAN	STD. DEVIATION
R1	0.0388	0.0000
R2	-0.0950	0.0495
R3	-0.0468	0.0284
R4	0.0000	0.0000
C1	0.2115	0.0000
C2	-0.1050	0.0072
C3	-0.1333	0.0071
C4	0.1559	0.0000
D1	0.1705	0.0000
D2	-0.3128	0.0000
D3	-0.2377	0.0638
D4	0.4221	0.0000
<hr/>		
F1	0.5160	0.0000
F2	-0.3639	0.0291
F3	-0.2283	0.0626
F4	0.0632	0.0000
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F1	0.3529	0.0000
F2	-0.3833	0.0000
F3	-0.6937	0.0905
F4	-0.0004	0.0000

BLOCK NO = 144.33 NO OF EVENTS = 7

SUBARRAY MEAN STD.DEVIATION

R1	-0.0262	
R2	-0.0777	
R3	0.0610	
R4	0.2174	
C1	0.2377	
C2	-0.1502	
C3	-0.1106	
C4	0.2840	
D1	0.1441	
D2	-0.3343	
D3	0.1503	
D4	0.6480	
<hr/>		
E1	0.7850	
E2	-0.4479	4
E3	-0.1560	
E4	0.5973	
<hr/>		
F1	0.7139	4
F2	-0.3991	
F3	-0.0914	
F4	0.3879	

BLOCK NO = 144.33 NO OF EVENTS = 7

SUBARRAY MEAN STD.DEVIATION

R1	-0.0401	
R2	-0.0667	0.0959
R3	0.0900	0.0566
R4	0.1990	
C1	0.2597	
C2	-0.0811	0.0590
C3	-0.1177	0.0667
C4	0.2987	
D1	0.1687	
D2	-0.2119	0.1546
D3	0.2346	0.0751
D4	0.3871	
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E1	0.8561	
E2	-0.2257	0.0368
E3	0.0005	0.0921
E4	0.5973	
<hr/>		
F1	0.7828	0.0885
F2	-0.0239	0.0885
F3	-0.0182	0.0435
F4	0.3879	

BLOCK NO = (44.36)

NO OF EVENTS = 2

SUBARRAY	MEAN	STD. DEVIATION
R1	0.0285	0.0664
R2	0.0281	0.0780
R3	0.0308	0.0000
R4	0.2114	0.0025
C1	0.3097	0.0454
C2	0.0349	0.0024
C3	-0.0470	0.0414
C4	0.2332	0.0000
D1	0.2702	0.0278
D2	-0.1509	0.0000
D3	0.1977	0.0420
D4	0.6985	0.0000
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F1	0.9543	0.0137
F2	-0.1428	0.0161
F3	0.2771	0.1007
F4	0.5155	0.0030
<hr/>		
F1	0.6945	0.0000
F2	-0.0567	0.1392
F3	0.0095	0.0000
F4	0.4947	0.1169

BLOCK NO = (44.37)

NO OF EVENTS = 10

SUBARRAY	MEAN	STD. DEVIATION
R1	0.0310	0.0558
R2	-0.0837	0.0782
R3	-0.0703	0.1238
R4	0.1347	0.0852
C1	0.2345	0.1442
C2	-0.0071	0.0864
C3	-0.0977	0.0434
C4	0.2614	0.0715
D1	0.2553	0.0715
D2	-0.1443	0.0875
D3	0.1243	0.0867
D4	0.6874	0.3796
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F1	0.8544	0.0969
F2	-0.2211	0.0522
F3	0.1562	0.1382
F4	0.3715	0.0788
<hr/>		
F1	0.8075	0.4350
F2	-0.1050	0.0674
F3	-0.0262	0.0754
F4	0.5497	0.1308

SUBARRAY	MEAN	STD. DEVIATION
B3	-0.0208	0.0000
B4	0.0000	-0.0000
C3	-0.1628	0.2302
C4	-0.0199	0.0709
D3	-0.3023	0.2216
D4	0.2784	0.2204
E3	-0.2231	0.0896
E4	0.1427	0.0527
F3	-0.4195	0.3434
F4	0.0478	0.0525

BLOCK NO = (45.32) NO OF EVENTS = 3

SUBARRAY	MEAN	STD. DEVIATION
H2	-0.0968	0.1548
B3	0.0235	0.0497
C2	0.0000	-0.0000
C3	-0.0181	0.0000
D2	-0.1402	0.1452
D3	0.2749	0.2776
E2	-0.2671	0.2676
E3	-0.0354	0.0458
F2	-0.1545	0.1607
F3	0.0453	0.0304

BLOCK NO = (45.34)

NO OF EVENTS = 4

SUBARRAY	MEAN	STD. DEVIATION
R1	0.0336	0.0407
R2	-0.0395	0.0366
R3	0.0815	0.0792
R4	0.1980	0.1416
C1	0.2417	0.0353
C2	-0.0340	0.0758
C3	0.0043	0.0414
C4	0.2804	0.0314
D1	0.1634	0.0173
D2	-0.1736	0.1269
D3	0.2255	0.0331
D4	0.6510	0.0695
<hr/>		
E1	0.7920	0.0000
E2	-0.1630	0.0000
F3	0.0478	0.1161
F4	0.5047	0.0431
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F1	0.7502	0.0550
F2	0.1720	0.1174
F3	0.0393	0.0557
F4	0.6584	0.0509

BLOCK NO = (45.36)

NO OF EVENTS = 3

SUBARRAY	MEAN	STD. DEVIATION
R1	-0.0743	0.0000
R2	-0.0126	0.0000
R3	0.0598	0.0672
R4	0.1466	0.1518
C1	0.2745	0.2759
C2	0.0377	0.0450
C3	-0.0521	0.0408
C4	0.2726	0.0435
D1	0.2233	0.0548
D2	-0.1022	0.1040
D3	0.2414	0.0804
D4	0.6655	0.0000
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E1	0.8128	0.0204
F2	-0.2047	0.0000
F3	0.1378	0.1518
F4	0.4933	0.0702
<hr/>		
F1	0.7658	0.0000
F2	0.0822	0.0000
F3	-0.0060	0.0000
F4	0.7925	0.0000

Model Number: 55 mm. (a) S. D. 100. 100.

BLOCK NO =

SUBARRAY	MEAN	STD. DEVIATION
B1	-0.0000	
B2	-0.0000	
B3	0.0878	
B4	0.1477	
C1	0.0000	
C2	0.0240	
C3	-0.0565	
C4	0.0000	
D1	0.0000	
D2	-0.0000	
D3	0.2577	
D4	0.6291	
E1	0.0000	
E2	-0.2059	
F3	0.0239	
F4	0.4492	
G1	0.7917	
G2	0.0579	
F3	0.0098	
F4	0.5653	

BLOCK NO = (47. 5) NO OF EVENTS = 1

SUBARRAY	MEAN	STD. DEVIATION
B1	-0.0071	
B2	-0.0046	
B3	-0.0200	
B4	0.0000	
C1	0.0000	
C2	-0.1807	
C3	-0.0716	
C4	0.0000	
D1	0.0000	
D2	-0.0022	
D3	0.1532	
E1	0.0000	
E2	-1.0024	
F3	-0.2166	3
G1	0.0000	
F2	-0.9968	
F3	0.2320	2

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BLOCK NO = (47.34) NO OF EVENTS = 3

SUBARRAY	MEAN	STD. DEVIATION
R1	-0.0450	0.0420
R2	-0.0066	0.0709
R3	0.0343	0.0093
R4	0.1161	0.0054
C1	0.1580	0.0613
C2	-0.0255	0.0563
C3	-0.0343	0.0902
C4	0.2002	0.0324
D1	0.0994	0.0493
D2	-0.0562	0.1137
D3	0.1760	0.0420
D4	0.5205	0.0271
<hr/>		
F1	0.5644	0.0311
F2	-0.1367	0.0608
F3	-0.0439	0.0752
F4	0.3203	0.0669
<hr/>		
F1	0.7727	0.0305
F2	0.1695	0.1845
F3	-0.0949	0.0494
F4	0.4381	0.0434

BLOCK NO = (47.35) NO OF EVENTS = 3

SUBARRAY	MEAN	STD. DEVIATION
R1	-0.0295	0.0544
R2	-0.0436	0.0238
R3	-0.0076	0.0951
R4	0.0913	0.0562
C1	0.1083	0.0955
C2	0.0093	0.0942
C3	-0.0462	0.0878
C4	0.1235	0.1157
D1	0.0908	0.0775
D2	-0.0247	0.0418
D3	0.1904	0.0455
D4	0.4920	0.0737
<hr/>		
F1	0.6182	0.1116
F2	-0.1449	0.1433
F3	-0.0273	0.0860
F4	0.3202	0.0698
<hr/>		
F1	0.6540	0.1142
F2	0.1299	0.1024
F3	-0.0672	0.0922
F4	0.3998	0.4154

SUBARRAY MEAN STD. DEVIATION

R1 -0.0071
 R2 -0.0081
 R3 -0.0127
 R4 0.0873
 C1 0.1415
 C2 -0.00476
 C3 -0.1300
 C4 0.2379
 D1 0.1548
 D2 -0.0269
 D3 0.1745
 D4 0.5591
 E1 0.0000
 E2 0.0000
 F3 0.0000
 F4 0.0000
 F1 0.0000
 F2 0.0000
 F3 0.0000
 F4 0.0000

BLOCK NO = (48.34) NO OF EVENTS = 3

SUBARRAY MEAN STD. DEVIATION
 R1 -0.0040
 R2 -0.0097 0.0295
 R3 0.0375 0.0450
 R4 0.0000
 C1 0.0000
 C2 0.0086 0.0358
 C3 -0.0512 0.1333
 C4 0.2110
 D1 0.1479
 D2 0.0124 0.0000
 D3 0.2140 0.2166
 E1 0.0000
 F2 0.0711 0.0915
 F3 -0.0920 0.0989
 F4 0.0000
 F1 0.7195
 F2 0.0829 0.0622
 F3 -0.2405 0.2807

BLOCK NO = (49.23) NO OF EVENTS = 1

SUBARRAY	MEAN	STD. DEVIATION
R1	0.0573	
R2	-0.0445	
R3	0.2025	
R4	0.1461	
C1	0.2689	
C2	0.2353	
C3	0.0000	
C4	0.0000	
D1	0.0721	
D2	0.0240	
D3	0.0000	
D4	0.2824	
<hr/>		
F1	0.2410	
F2	0.2659	
F3	0.0853	
F4	-0.2168	
<hr/>		
F1	0.1528	
F2	0.1738	
F3	0.2471	
F4	-0.0502	

BLOCK NO = (49.25) NO OF EVENTS = 3

SUBARRAY	MEAN	STD. DEVIATION
R1	-0.0038	0.0865
R2	-0.0157	0.1250
R3	0.0621	0.0441
R4	0.0555	0.0758
C1	0.0748	0.0445
C2	-0.1404	0.1464
C3	-0.0378	0.0309
C4	0.1532	0.0505
D1	-0.0265	0.0749
D2	-0.0944	0.1043
D3	0.1666	0.0377
D4	0.5958	0.5958
<hr/>		
F1	0.6710	0.6726
F2	-0.1555	0.4114
F3	-0.1140	0.0789
F4	0.2281	0.1601
<hr/>		
F1	0.4044	0.4386
F2	-0.2338	0.6426
F3	-0.0201	0.2398
F4	0.1897	0.2425

BLOCK NO = (49.331)

NO OF EVENTS = 5

SUBARRAY MEAN STD. DEVIATION

B1	-0.0134	0.0490
B2	-0.0732	0.0801
B3	0.0166	0.0193
B4	0.1146	0.1190
C1	0.1527	0.0545
C2	-0.0310	0.0670
C3	-0.1011	0.1157
C4	0.1927	0.0398
D1	0.1399	0.1064
D2	-0.1168	0.0000
D3	0.1681	0.0873
D4	0.5502	0.5505
<hr/>		
E1	0.5765	0.9527
E2	-0.0142	0.1032
E3	-0.1497	0.0328
E4	0.2665	0.0611
<hr/>		
F1	0.6810	0.3526
F2	-0.0038	0.0317
F3	-0.3205	0.1860
F4	0.5514	0.0977

BLOCK NO = (49.341)

NO OF EVENTS = 2

SUBARRAY MEAN STD. DEVIATION

B1	-0.0992	0.0000
B2	-0.0812	0.0000
B3	-0.0172	0.0000
B4	0.0071	0.0000
C1	0.1756	0.0000
C2	0.0109	0.0000
C3	-0.2956	0.0000
C4	0.1872	0.0000
D1	0.1522	0.0000
D2	-0.0378	0.0000
D3	0.1708	0.0000
D4	0.5575	0.0000
<hr/>		
E1	0.4514	0.0000
E2	-0.0035	0.0508
E3	-0.0755	0.0993
E4	0.2883	0.0000
<hr/>		
F1	0.5934	0.0335
F2	0.0671	0.0838
F3	-0.4074	0.0000

BLOCK NO = (49.48) NO OF EVENTS = 1

SUBARRAY	MEAN	STD. DEVIATION
B1	0.0000	
B2	0.0000	
B3	0.0000	
B4	0.0000	
C1	0.2945	
C2	-0.0469	
C3	-0.0768	
C4	0.0000	
D1	0.1951	
D2	0.0000	
D3	0.0078	
D4	0.3660	
<hr/>		
F1	0.6324	
F2	0.0663	
F3	0.6759	
F4	0.0000	
<hr/>		
F1	0.5912	
F2	0.0000	
F3	0.0000	
F4	0.0000	

BLOCK NO = (50.29) NO OF EVENTS = 1

SUBARRAY	MEAN	STD. DEVIATION
B1	-0.0994	
B2	0.0000	
B3	0.0471	
B4	0.0771	
C1	0.0651	
C2	0.0000	
C3	-0.0585	
C4	0.1464	
D1	-0.0758	
D2	-0.1202	
D3	0.1653	
D4	0.5208	
<hr/>		
F1	0.6021	
F2	-0.3851	
F3	-0.1539	
F4	0.3052	
<hr/>		
F1	0.5652	
F2	-0.4508	
F3	-0.1377	
F4	0.2830	

BLOCK NO = (50.31)

NO OF EVENTS = 2

SUBARRAY	MEAN	STD. DEVIATION
B1	-0.0699	0.0752
B2	-0.0610	0.1693
B3	0.0048	0.0383
B4	0.0265	0.0488
C1	0.1402	0.0390
C2	-0.0426	0.0000
C3	-0.0096	0.0378
C4	0.1889	0.0033
D1	0.0166	0.0241
D2	-0.1359	0.0028
D3	0.2431	0.0000
D4	0.5156	0.0000
E1	0.6910	0.0648
E2	-0.1119	0.0006
F3	-0.2352	0.0000
F4	0.2219	0.0911
F1	0.8459	0.0151
F2	-0.0282	0.0116
F3	-0.2943	0.0000
F4	0.6950	0.0109

BLOCK NO = (50.32)

NO OF EVENTS = 6

SUBARRAY	MEAN	STD. DEVIATION
B1	-0.1232	0.0888
B2	-0.0182	0.0522
B3	-0.0129	0.0727
B4	0.0913	0.0633
C1	0.0250	0.0888
C2	-0.0102	0.0697
C3	-0.0707	0.0926
C4	0.1715	0.0657
D1	0.0525	0.0888
D2	-0.1308	0.1675
D3	0.1775	0.1731
E1	0.5944	0.0888
E2	-0.1419	0.1260
E3	-0.0889	0.0564
E4	0.3324	0.0888
F1	0.6629	0.5415
F2	-0.0321	0.1288
F3	-0.2088	0.0769
F4	0.3927	0.0888

BLOCK NO = 151.261

NO OF EVENTS = 1

SUBARRAY MEAN STD. DEVIATION

B1	0.0000
B2	-0.1588
B3	0.0366
B4	0.0000
C1	-0.0066
C2	0.0000
C3	0.0000
C4	0.1659
D1	-0.1315
D2	0.0000
D3	0.1405
D4	0.4534

F1	0.0000
F2	-0.3840
F3	-0.2144
F4	0.2957

F1	0.0000
F2	-0.5149
F3	-0.1105
F4	0.0000

BLOCK NO = 151.301

NO OF EVENTS = 1

SUBARRAY MEAN STD. DEVIATION

B1	-0.0325
B2	-0.0956
B3	0.1043
B4	0.1641
C1	-0.0815
C2	0.0687
C3	0.0216
C4	0.1339
D1	0.0835
D2	-0.0870
D3	0.1602
D4	0.5062

F1	0.6252
F2	-0.1217
F3	-0.0408
F4	0.2961

F1	0.8394
F2	0.0607
F3	-0.0713
F4	0.7239

BLOCK NO = (52.20)

NO OF EVENTS = 1

SUBARRAY MEAN STD.DEVIATION

B1 -0.0775

B2 -0.0237

B3 0.0885

B4 0.0516

C1 0.0072

C2 -0.0778

C3 -0.0310

C4 0.1572

D1 -0.0364

D2 -0.1993

D3 0.1914

D4 0.5007

E1 0.6050

E2 -0.1135

F3 -0.1995

F4 0.2912

F1 0.0000

F2 -0.0819

F3 0.0438

F4 0.5560

BLOCK NO = (52.30)

NO OF EVENTS = 1

SUBARRAY MEAN STD.DEVIATION

B1 0.0000

B2 0.0000

B3 0.0000

B4 0.0000

C1 0.0571

C2 -0.0996

C3 0.0000

C4 0.1521

D1 0.0281

D2 -0.1669

D3 0.1644

D4 0.0000

E1 0.4965

F2 0.0000

F3 -0.2135

F4 0.2834

F1 0.6791

F2 0.0650

F3 -0.0245

F4 0.5567

BLOCK NO = (53,23) NO OF EVENTS = 1

SUBARRAY	MEAN	STD. DEVIATION
R1	-0.1614	
R2	0.0314	
R3	0.0961	
R4	0.1673	
C1	0.0201	
C2	-0.0389	
C3	0.0505	
C4	0.1371	
D1	-0.1025	
D2	0.0000	
D3	0.2125	
D4	0.5036	
<hr/>		
F1	0.4237	
F2	-0.2686	
F3	-0.1469	
F4	0.2507	
<hr/>		
F1	0.1564	
F2	-0.3000	
F3	-0.0011	
F4	0.2915	

BLOCK NO = (53,24) NO OF EVENTS = 2

SUBARRAY	MEAN	STD. DEVIATION
R1	0.0000	-0.0000
R2	0.0000	-0.0000
R3	0.1131	0.0000
R4	0.0814	0.0000
C1	0.0089	0.0000
C2	-0.0188	0.0034
C3	0.0460	0.0286
C4	0.1566	0.0032
D1	-0.1622	0.0000
D2	-0.1911	0.0107
D3	0.2184	0.0454
D4	0.4913	0.0077
<hr/>		
F1	0.3793	0.0000
F2	-0.3902	0.0145
F3	-0.0911	0.0904
F4	0.2525	0.0682
<hr/>		
F1	0.0000	-0.0000
F2	-0.3255	0.0000
F3	-0.0605	0.0570
F4	0.4269	0.0520

BLOCK NO = (56. 22)

NO OF EVENTS

SUBARRAY MEAN STD. DEVIATION

R1	-0.1780	0.0697
R2	-0.0647	0.0709
R3	0.0718	0.0563
R4	0.0440	0.0353
C1	-0.0155	0.0155
C2	-0.0726	0.0571
C3	0.0227	0.0495
C4	0.1548	0.0067
D1	-0.1618	0.0204
D2	-0.0980	0.0996
D3	0.1687	0.0701
D4	0.0619	0.0844
F1	0.3212	0.0028
F2	-0.3871	0.0754
F3	-0.0152	0.0302
F4	0.1736	0.0126
F1	-0.0821	0.03
F2	-0.1068	0.03
F3	0.1329	0.0266
F4	0.0907	0.1185

BLOCK NO = (58. 5)

NO OF EVENTS = 1

SUBARRAY MEAN STD. DEVIATION

R1	-0.1776	
R2	-0.1702	
R3	-0.1419	
R4	0.0000	
C1	-0.1001	
C2	0.0000	
C3	-0.2424	
C4	0.0066	
D1	-0.2788	
D2	-0.1924	
D3	-0.0079	
D4	0.1850	
F1	0.0845	
F2	-0.7921	
F3	0.0945	
F4	0.3637	
F1	-0.6256	
F2	-0.7395	
F3	-0.1112	
F4	0.9022	



APPENDIX B
CORRECTIONS FOR DEPARTURES FROM SPACE STATIONARITY
WHEN COMPUTING WAVENUMBER SPECTRA

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APPENDIX B
CORRECTIONS FOR DEPARTURES FROM SPACE STATIONARITY
WHEN COMPUTING WAVENUMBER SPECTRA

The assumption of space stationarity necessary for the computation of meaningful wavenumber spectra may not prove to be valid for large-diameter arrays such as LASA. Departures from the assumed plane wavefront of constant waveform moving at constant velocity may be due to two primary factors: the first is instrument response variations and should be independent of wavenumber; the second is the effect introduced by different crustal paths and different seismometer-to-earth couplings. Upper mantle inhomogeneities, due to variations in thickness and composition, will probably be a function of wavenumber. If the total effect of these two factors can be determined theoretically or empirically, corrections for departures from space stationarity may be easily made as follows.

Let $H_j(w, \vec{k})$ be the transfer function of the filter which equalizes the j^{th} seismometer (or subarray) to the r^{th} or reference seismometer (or subarray). To compute the power density at frequency w and wavenumber \vec{k} , the matrix ϕ of auto- and crosspower spectra should be premultiplied by T and postmultiplied by T^* as shown:

$$\begin{bmatrix} H_1(w, \vec{k}) & 0 & \dots & 0 \\ 0 & H_2(w, \vec{k}) & \dots & 0 \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ 0 & 0 & \dots & H_N(w, \vec{k}) \end{bmatrix} \begin{bmatrix} \phi_{11}(w) & \phi_{12}(w) & \dots & \phi_{1N}(w) \\ \phi_{21}(w) & \phi_{22}(w) & \dots & \phi_{2N}(w) \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \phi_{N1}(w) & \phi_{N2}(w) & \dots & \phi_{NN}(w) \end{bmatrix} \begin{bmatrix} H_1^*(w, \vec{k}) & 0 & \dots & 0 \\ 0 & H_2^*(w, \vec{k}) & \dots & 0 \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ 0 & 0 & \dots & H_N^*(w, \vec{k}) \end{bmatrix} = T \phi T^*$$



When computing high-resolution wavenumber spectra (estimating the signal at location j) for the spatially random signal model case, the matrix equation solved for the filter responses $F_1(w)$, $F_2(w)$, ..., $F_n(w)$ is

$$F^* = \Sigma^{-1} \psi$$

where

$$\Sigma = \begin{bmatrix} \phi_{11}(w) + \frac{K(w)}{|H_1(w)|^2} & \phi_{12}(w) & \dots & \phi_{1N}(w) \\ \phi_{21}(w) & \phi_{22}(w) + \frac{K(w)}{|H_2(w)|^2} & \dots & \phi_{2N}(w) \\ \vdots & \vdots & \ddots & \vdots \\ \phi_{N1}(w) & \phi_{N2}(w) & \dots & \phi_{NN}(w) + \frac{K(w)}{|H_N(w)|^2} \end{bmatrix}$$

$$\psi = \begin{bmatrix} 0 \\ \vdots \\ 0 \\ \frac{K(w)}{|H_j(w)|^2} \\ \vdots \\ 0 \end{bmatrix}$$

$$F^* = \begin{bmatrix} F_1^*(w) \\ F_2^*(w) \\ \vdots \\ F_N^*(w) \end{bmatrix}$$



To correct for departures from space stationarity, we should solve the matrix equation

$$T \sum T^* F_c^* = H_j^*(w) T \psi \quad (B-1)$$

or

$$F_c^* = H_j^*(w) [T^*]^{-1} \sum^{-1} T^{-1} T \psi \quad (B-2)$$

$$F_c^* = H_j^*(w) [T^*]^{-1} \sum^{-1} \psi = H_j^*(w) [T^*]^{-1} F^*$$

Thus, the corrected filter responses may be obtained from the uncorrected filter responses from Equation B-2 more simply than through the solution of Equation B-1.

A similar result is obtained for the multichannel Markov case for the correction to the spatial prediction filter responses. The equation to be solved for the filter to predict the N+1th channel now is

$$T \Phi T^* F_c^* = H_{N+1}^*(w) T \Gamma$$

where

$$\Gamma = \begin{bmatrix} \phi_{1,N+1}(w) \\ \phi_{2,N+1}(w) \\ \vdots \\ \phi_{N,N+1}(w) \end{bmatrix}$$



Therefore,

$$F_c^* = [T^*]^{-1} \phi^{-1} T^{-1} T \Gamma F_{N+1}^*(w) = H_{N+1}^*(w) [T^*]^{-1} \phi^{-1} \Gamma$$

or

$$F_c^* = H_{N+1}^*(w) [T^*]^{-1} F^*$$

where

$$F^* = \phi^{-1} \Gamma$$

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13. ABSTRACT

This report investigates practical aspects of generating high-resolution wavenumber spectra using subarray outputs of the Montana LASA. Especially studied are the variability of traveltime anomalies as a function of wavenumber, spectral window effect on crosspower estimates due to moveout across the array, and tradeoffs involved in a finite-length transform of array data. From this investigation, it is concluded that current data are insufficient to define a scheme adequately to correct wavenumber spectra calculations for traveltime anomalies. Also, because subarrays on the E and F rings of LASA generally exhibit larger traveltime residuals and less waveform similarity than do subarrays of the inner rings, subarrays on the E and F rings will not be included in high-resolution f-k spectra calculations. ()

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KEY WORDS

LINK A

LINK B

LINK C

ROLE

WT

ROLE

WT

ROLE

WT

Large-Array Signal and Noise Analysis
Traveltime Analysis
High-Resolution Wavenumber Spectra
Spectral Window Effects