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**OBJECTIVE ANALYSIS WITH POINT CUMULATIVE
SEMIVARIOGRAM IN METEOROLOGY**

M.Sc. THESIS

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METEOROLOJİDE NOKTA SEMİVARIÖGRAM

İLE OBJEKTİF ANALİZ

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LIST OF SYMBOLS

Δx	constant grid size in x-direction.
Δy	constant grid size in y-direction.
$i_{\max}$	maximum grid points in x-direction.
$j_{\max}$	maximum grid points in y-direction.
ϕ	any latitude.
λ	any longitude.
m	map-scale factor.
ϕ_0	standard parallel latitude.
λ_0	longitude of map original point.
CSV	the cumulative semivariogram.
D_{c_i}	the scalar distance between any two points.
D_R	the scalar distance between reference point and another surrounding stations.
ΔZ_R	the-half-squared differences of meteorological data between reference point and all other stations in study area.
ΔZ_{c_i}	the-half-squared differences of meteorological data between any two points.
γ_{c_i}	theoretical cumulative semivariogram.
γ_R	theoretical point cumulative semivariogram.
α	the scale parameter of power model.
β	the shape parameter of power model.
Z	any meteorological regional variable.
m_c	the number of distances between n observation stations.
m_p	the number of distances between reference point and all other stations in study area.

n	number of observation stations.
SCM	successive correction method .
MSCM	modification of the successive correction method.
W_k	the weighting factor.
R	influence of radius.
$Y_{p_{max}}$	the maximum point CSV.
GMT	Greenwich Meridian Time.
η	constant for smoothing for SCM.



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SUMMARY

The main purpose of the thesis is to develop a new technique in objective analysis by using point cumulative semivariogram , and compare it with some of the powerful objective analysis methods such as successive correction method.

It is possible to define the point cumulative semivariogram as a measure of variability around any single station by considering other station effects on this station which will be referred here onward as the reference point. The main reason of finding the point cumulative semivariogram is for determining the radius of influence which plays a major role in objective analysis.

A modification of an objective analysis proposed here as the modification of successive correction method has only one scanning operation and it does account for the distribution of observation relative to each other.

The results in this research indicate that the new method for objective analysis given comparatively the best results in term of accuracy, especially for sparse station densities. The methodology of this research has been applied to pressure data around and within Turkey.

ÖZET

METEOROLOJİDE NOKTA SEMİ- VARIOGRAM İLE OBJEKTİF ANALİZ

Sıcaklık, basınç, nem, yağış ve benzeri gibi meteorolojik değişkenler zamansal değişimlerine ilave olarak bir alan üzerinde de değişimler gösterirler. Bu değişkenlerin yer istasyonlarında zaman ile olan sürekli ölçümlerine rağmen alansal süreklilik ancak birbirinden yerine göre kilometrelerce uzakta olan istasyonlar vasıtası ile yapılır. Hava tahminlerinin yapılmasında değişkenlerin haritalarının çizilmesi ana hedeftir. Burada karşılaşılan güçlük ayırık olan istasyon verilerinden haritaların en iyi bir biçimde yapılmasıdır. Bu amaçla geliştirilmiş değişik yöntemler bulunmaktadır.

Bu yöntemlerin başında çok eskiden beri kullanıla gelen el ile kontur eğrilerinin çizilmesi gelir. Bu yöntem ile çizilen haritanın sağlığı onu çizen şahsın bilgisine, becerisine ve tecrübesine çok bağlı olacağından değişik kişiler tarafından yapılan haritaların da birbirinden bazen önemli derecede farklı olması muhtemeldir. Bu sebeple bu yöntemler 'subjektif' olduklarından çoğu zaman küçük te olsa görüş ayrılıklarına yol açarlar. Bu bakımdan kişisel olmayan 'objektif' yöntemlerin geliştirilmesi işine 1955 yıllarında Bergthorsson ve Döös tarafından sunulan matematik esaslı bir yöntemle başlanmıştır. Objektif yöntemlerin gayesi kullanıcıdan kullanıcıya değişmeyen ve aynı verilerle yöntemin tatbik edilmesi halinde aynı sonuçlara varılmasıdır. Bu yöntemler incelenen olayın öz karakteristiklerini göz önünde tutacak biçimde geliştirilmişlerdir. O günden bu güne kadar değişik veya esasta aynı olupta bazı küçük ilavelerle ileriye sürülmüş birçok yöntem bulunmaktadır. Bütün bu yöntemlerin uygulanmasında takip edilen sıra aşağıdaki gibi olmuştur.

- (i) gelişmiş güzel yani düzensiz bir şekilde dağılmış olan istasyonlardan elde edilen gözlemlerin içerdiği bilgilerin bir şebekedeki düzenli olan düğüm noktalarına aktarılması,
- (ii) veya düzenli olan düğüm noktalarında mevcut olan harita bilgilerinin düzensiz istasyon noktalarına aktarılması.

Bunlardan birinci adım istasyon verilerinden yararlanarak haritaların yapılması için gerekli olan düğüm noktası veri tahminlerinin yapılmasına karşı gelir. Bu adımın değer bir faydası da sayısal hava öngörü yöntemlerinin uygulanabilmesi için gerekli olan düzgün

şebekelerin belirlenmesinden sonra düğüm noktası değerlerinin tesbitini takiben differansiyel denklemlerin sonlu farklar yöntemi ile çözümlerinin yapılarak zamansal hava tahminlerinde bulunmaktadır. Literatürden açıkça görülmektedir ki bu tür tahminlerin en zor aşamalarından biri düzensiz istasyon verilerinin düzenli düğüm noktalarına intikal ettirilmesidir.

Yukardaki adımlardan ikincisi ise yapılan tahminlerin doğruluklarını tesbit etmek ve geleceğe yönelik tahminlerin daha kısa ve ardışık yaklaşımlarla bulunabilmesi için etkin yöntemlerin geliştirilmesinde faydalar vardır.

Gözlemlerin düzgün noktalara taşınmasında kullanılan yöntemlerin esasını daha ziyade mesafeye göre değişimleri göz önünde tutan ağırlıklı ortalamalar alır. Bunların en basitini ters-kare-mesafe yöntemi teşkil etmektedir. Ancak bu yöntem sadece mesafeye bağlı kaldığı için istasyonlarda ölçülen meteorolojik olayların yapılarındaki karakteristik değişimleri ihmal eder. Bu bakımdan kullanılması çok süratli sonuca getirmesine rağmen fiziksel hiçbir dayanağı olmadığı için mahzurludur. Bu mahzurları ortadan kaldırmak için araştırmacıların geliştirdikleri yöntemlerden bir diğeri de fonksiyon uydurma yöntemi olmuştur. Bu yöntemde yer bilimleri literatüründe 'trend uydurma' yöntemi de adı verilir. Bunun amacı bir bölgedeki istasyonların konumları (enlem ve boylamları veya belirli bir başlangıç noktasını esas alarak istasyon noktalarının koordinatları) ile gözlenen değerleri arasında bağıntı kurulmasıdır. Burada herhangi bir meteorolojik değişkenin alansal değişimlerinin konum koordinatlarına bağlı olarak fonksiyonunun bulunmasına uğraşılır. Bu yöntemin kullanılmasından vaz geçilmiştir çünkü meteorolojik değişkenin kendisine has olan değişimleri fiziksel nedenlere değil, olay istasyonun konum koordinatlarına bağlanmıştır. Böylece bir ölçüye kadar bölgenin topoğrafyası işin içine katılmış olması ters-kare-mesafe yöntemine göre bir üstünlük arz etmektedir.

Meteorolojide en yaygın olarak kullanılan yöntem ise 1959 yılında Cressman tarafından ortaya atılan ve her istasyon için sabit olduğu kabul edilen dairesel etki alanının yarı çapının belirlenmesi ile başlamıştır. Buradaki fiziksel ve mantıksal kavram bir istasyondaki verilerin komşu istasyon verileri ile olan ilişkisinin aradaki mesafe ile ters orantılı olarak azaldığı esasına dayanmaktadır. Böylece bir istasyon verisinin belirtilen yarıçaplı dairesel alan içinde kalan istasyonların verileri ile ağırlıklı ortalama kavramı ile bağıntılı oldukları ortaya çıkar. Böyle bir yarıçapın belirlenmesi bu yöntemin en kritik noktasını teşkil eder. Cressman yöntemin uygulanmasında önce 1500, sonra 700 ve daha da sonra 300 metre gibi ampirik olarak tesbit ettiği ve iyi sonuç verdiğini belirttiği yarıçapları ardışık olarak uygulayarak düğüm noktası değerlerini bulmuştur. Bu yöntemde uzun yıllar özellikle A.B.D.'de kullanılmıştır. Yöntemin tenkit edilecek noktası yarıçapların belirlenmesindeki sübjektifliktir.

Daha sonraki çalışmalarda Tiebaux ve Tedder(1987) tarafından istasyonlar arasındaki korelasyonların hesaplanarak yarıçap tayini yönünde teklifler yapılmıştır. Bu teklif ile önerilen yöntemim esasında olayın fiziksel yapısı diğer yöntemlere göre daha fazla yansıtılmış olmaktadır. Yarıçap olarak korelasyonun sıfıra yaklaştığı ortalama mesafe alınmıştır. Böylelikle yarıçap belirlenmesindeki sübjektiflik ortadan kaldırılmış olmaktadır. Ancak Gerek bu yazarlar ve gerekse Cressman tarafından sunulan yöntemlerdeki yarıçapların tüm mülrika için gerekli olduğunun kabulü pek gerçekte uyuşmaz. Çünkü bir bölgedeki meteorolojik olayın gelişmesinde atmosferik olaylar ile yeryüzü şekillerinin rol oynadığı düşünülürse tüm bölge için sabit bir yarıçap yerine herbir istasyon için değişik olabilecek yarıçapların belirlenmesi gerekmektedir. Böyle bir yöntem her ne kadar fazla zaman almaktaysa da varılan sonuçların daha sağlıklı olacakları aşıkardır. Diğer bir önemli nokta da bu tür yarıçapların aynı bir istasyon için zamanla da değişken olmasıdır. Elastik diyebileceğimiz böyle bir yarı çapın belirlenebilmesi için ilk düşünceler bu çalışmada ortaya sürülerek gerekli yöntem yer bilimlerinde güncel olarak çok kullanılan 'Kriging' yönteminin esasını teşkil eden variogramlardan esinlenerek sunulmuştur.

Bu çalışmada yerbilimleri literatürüne Şen(1989) tarafından bölgesel jeolojik değişkenlerin haritalarının çizilmesi için teklif edilmiş olan 'Toplam Semi-variogram' yöntemi değiştirilerek uygulanmıştır. pimdiye kadar literatürde görülmemiş 'Noktasal Toplam Semi-variogram' yönteminin esasları bu çalışmada atılarak uygulamalar Türkiye'yi de içine alan bir bölge için yapılmış ve elde edilen sonuçlar meteoroloji literatüründe en sık kullanılan ardışık düzetmeler yöntemi ile karşılaştırılmıştır. Noktasal Toplam Semi-Variogram'ın elde edilmesi aşağıdaki adımlardan sonra mümkündür.

- (i) Belirli bir istasyon ile diğer istasyonlar arasındaki mesafeleri hesap ederek bul,
- (ii) her iki istasyonda yapılan meteorolojik gözlemlerin aralarındaki farkların karelerini hesapla. Böylece herbir mesafeye karşı gelen bir fark karesi değeri vardır.
- (iii) birinci adımda bulunan mesafeleri küçükten büyüğe doğru sıralayarak diz ve aynı zamanda ikinci adımdaki değerleri de bu mesafe dizimleri ile birlikte hareket ettir,
- (iv) ardışık olarak fark karelerini topla,
- (v) mesafe yatay eksende toplam fark kareleri düşey eksende olacak şekilde milimetrik kağıtta noktaları göster
- (vi) elde edilen sonuç grafik noktasal toplam semi-variogram, (NTSM) olarak adlandırılır.

Böylece elde edilen şekil verilerden elde edildiği için ona örnek noktasal toplam semi-variogram adı verilir. Bu grafik bir anlamda istasyonlar arasındaki alansal bağıntıyı ifade eder. Yapılan çalışmada göz önüne alınan basınç verilerinin alansal dağılımlarının NTSM'lerinde aşağıdaki

özellikler görülmüştür.

- (i) genelde NTSM iki kısımdan oluşur. Bunlardan birincisi küçük mesafeler boyunca olan eğrisel kısım ile büyük mesafeler boyunca olan doğrusal kısımlardır.
- (ii) eğrisel kısmın eğriliği mesafe arttıkça azalır bu ise fiziksel olarak mesafe ile istasyonlar arasındaki korelasyonun azaldığı anlamına gelir.
- (iii) büyük mesafelerde doğruya yakın olarak seyreden NTSV kısmı ise korelasyonun ihmal edilecek kadar az olduğu anlamına gelir.
- (iv) NTSV grafiğindeki noktaların saçılımının az olması ve genelde belirli bir eğri boyunca az sapmalarla ortaya çıkmalarının önemli anlamı incelenen meteorolojik olayın o istasyon civarında homojen bir yapı gösterdiği anlamına gelir.

Bütün bu yorumlar da dikkate alınarak yapılan araştırmalar sonucunda bu araştırmadaki basınç değerlerinin teorik noktasal toplam semi-variogram'ların üssel (power) şeklinde bir modelle genel olarak temsil edilebileceği anlaşılmıştır. Böyle bir modelde birisi şekil diğeri ölçek olmak üzere iki tane birbirinden bağımsız parametre vardır. Bunun sonucu olarakta çalışmadaki her bir istasyonun parametreleri ayrı ayrı hesap edilmiştir. Model ve parametreler yardımı ile artık bir istasyon etrafındaki meteorolojik olayın alansal korelasyonlarını istenilen her nokta için hesap edebiliriz.

Ustel NTSV modelinin kullanılması ile her bir istasyona ait tesir yarı çapları ayrı ayrı hesap edilmiştir. Tesir çapları bulunmasında en büyük NTSV değerinin yarısına karşı gelen mesafe bu yarıçapa eşit kabul edilmiştir. Böylece elde edilen tesir yarı çaplarının o bölge üzerinde tesis edilen kontur haritaları vasıfası ile istenilen herhangi bir nokta için tesir yarıçapının otomatik olarak okunması mümkün olabilmektedir. Tabii ki böylelikle o bölge üzerinde düşünülen her türlü şebekenin düğüm noktalarının tesir yarı çaplarının da kolayca bulunması sağlanmış olur. Böyle bir haritanın tesir yarı çaplarının belirlenmesine ilaveten meteorolojik değişkenin yapısındaki bağımlılığın bölge içindeki dağılımı hakkında da yorumlar yapılabilir. Ayrıca meteorolojik olayın homojen dağılımlı olup olmadığı da görülebilir.

Meteorolojik verilerin öngörü haritalarının çizilmesinde Cressman yöntemi ve diğer yöntemlerinde esasını teşkil eden ağırlıklı ortalamalar formülündeki ağırlıklar yerine istasyon uzaklıklarına göre teorik noktasal toplam semi-variogram'dan değerler bulunarak uygulamalar yapılmıştır. Alansal tahmin yöntemi olarak ise literatürde çok yaygın kullanılan ardaşık düzeltmeler yönteminin NTSV kavramı ile birleştirilmesi ile ortaya çıkan yeni bir versiyon kullanılmıştır. Burada sunulan yeni yöntemin öncekilerden daha iyi olup olmadığının araştırılması için çapraz korelasyon metodu kullanılmıştır. Varılan önemli sonuçlar şunlardır.

- (i) az sıklıktaki bölgelerde sunulan yöntem diğer

- (ii) yöntemlerden çok daha iyi sonuçlar verir.
- (iii) bilgisayarda zaman açısından yeni yöntemin diğerlerinden fazla farkı olmamıştır.
- (iii) yeni yöntem gerçek haritalarla kıyaslandığında daha iyi sonuçlar vermiştir.

Bu çalışmada sunulan yöntem diğer meteorolojik verilere de uygulanarak gelecekte pratiğe dönük çalışmaların yapılması gerekir.

CHAPTER 1

INTRODUCTION

1.1 GENERAL

The main purpose of this study is to develop new method for representing regional variability changes around one single station within any study area, for calculating the radius of influence around that station. However the second purpose is modification of Successive Correction Method in Objective Analysis by using this new method.

The data employed for this study is surface pressure taken from 47 observation surface stations at 1200 Greenwich Meridian Time (GMT) on 19 June 1990. By using the polar stereographic projection, longitudes and latitudes are converted to Cartesian coordinates on a plane surface (see Table 1.1). Herein, the network has maximum grid points along x-axis as 9 grids and the maximum grid points along y-axis as 7 grids. Within this network the grid size is calculated as 300.5 km corresponding to 3° . Figure 1.1. illustrates the network of grid points and the distribution of observation stations in the study area.

The rectangular of grid points is centered at point with longitude 30°E and latitude is the standard parallel latitude in which 42.5°N .

One can get the impression from the data available in Table 1.1. that surface pressure system is defined by a weak cyclone with a central pressure of 1018 mb, which

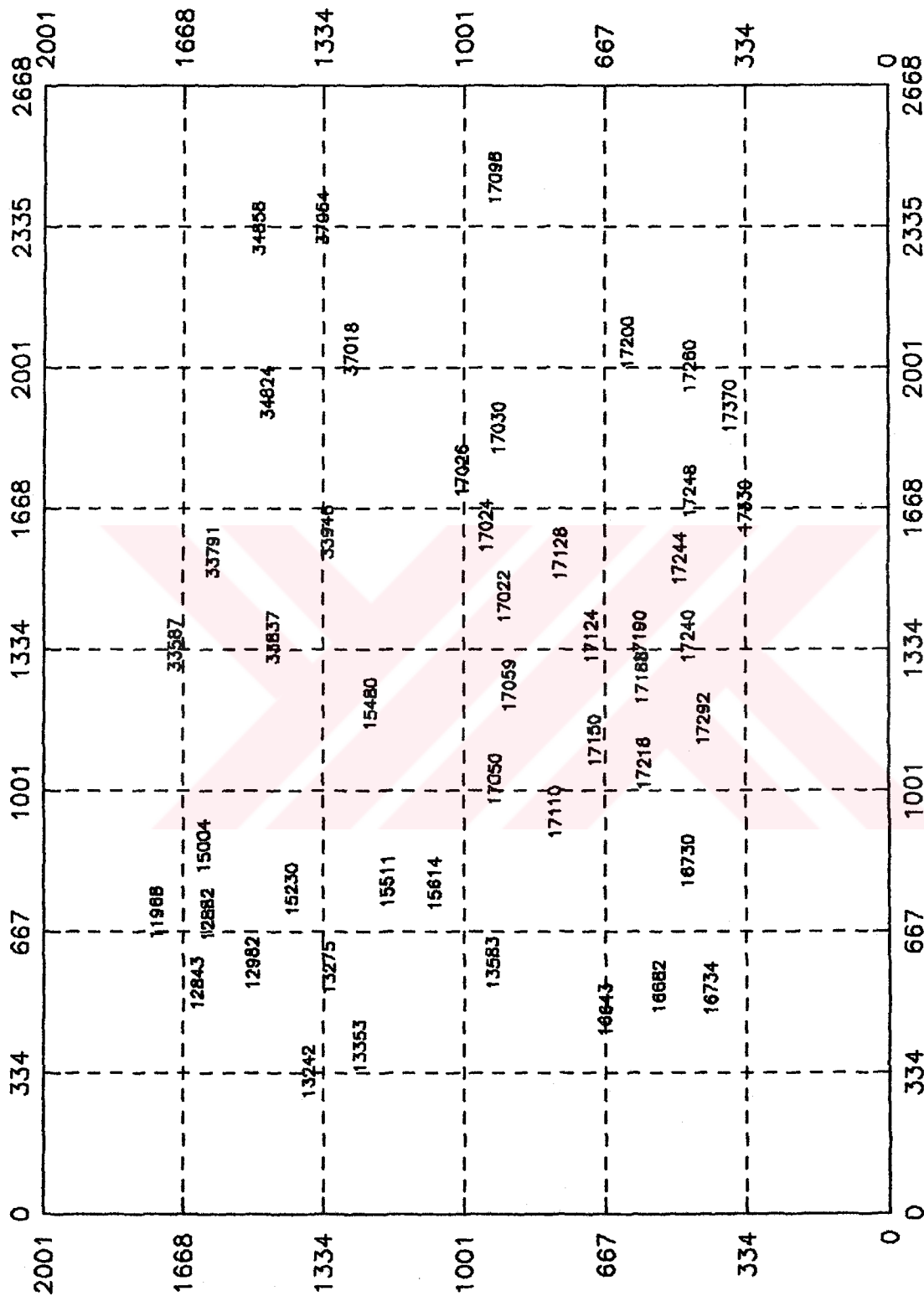


Figure 1.1. Grid points and observation stations.

was located in south east of study area, and high pressure was located in the center of the study area.

Table 1.1. Data used in this study.

Station no.	Latitude (° N)	Longitude (° E)	X (km)	Y (km)	Pressure (mb)
12843	47.26	19.11	545.09	1595.81	1017.6
12982	46.15	20.06	592.54	1465.41	1018.6
13242	44.47	17.13	336.46	1330.52	1017.1
13353	43.50	18.20	396.37	1208.26	1018.8
11968	48.42	21.16	711.38	1692.83	1016.0
15004	47.58	23.55	868.81	1581.15	1018.4
12882	47.29	21.38	708.64	1570.96	1018.4
15230	45.53	22.54	767.61	1370.60	1018.2
13275	44.47	20.32	580.99	1281.77	1018.1
15511	43.49	23.14	786.26	1143.08	1018.7
15614	42.49	23.23	780.36	1032.24	1017.1
13583	41.03	21.22	592.16	893.18	1016.2
16643	38.57	20.46	482.20	627.88	1019.8
16682	37.55	21.27	536.10	500.16	1018.1
16730	37.27	24.57	833.51	430.54	1017.1
16734	36.50	21.42	531.50	377.37	1018.4
33587	48.46	30.14	1344.02	1648.97	1017.1
15480	44.13	28.38	1206.45	1182.51	1019.0
17050	41.40	26.34	1026.49	887.60	1018.2
17059	41.18	29.00	1249.59	853.82	1017.9
17110	40.11	25.54	948.06	747.41	1018.5
17150	39.37	27.55	1118.31	652.90	1017.1
17188	38.40	29.25	1266.59	537.71	1016.4
17292	37.12	28.21	1168.34	391.97	1014.0
17218	38.30	27.01	1064.39	532.82	1016.4
33791	47.56	33.20	1565.47	1559.25	1016.1
33837	46.29	30.38	1362.52	1416.16	1017.6
33946	45.01	33.59	1610.89	1285.70	1016.3
17022	41.27	31.48	1458.98	864.80	1019.0
17024	41.59	33.47	1624.53	907.86	1019.5
17026	42.02	35.10	1756.37	965.93	1017.4

Table 1.1. Data used in this study. (Continue)

17128	40.07	32.59	1558.68	732.92	1018.2
17124	39.47	30.34	1364.02	659.77	1018.6
17190	38.45	30.32	1362.91	543.10	1017.1
17244	37.58	32.33	1547.74	447.06	1016.3
17240	37.45	30.33	1364.48	427.75	1015.2
17248	37.30	34.04	1706.6	423.41	1015.8
17330	36.22	33.56	1670.22	294.85	1012.0
34824	46.02	38.09	1940.7	1429.74	1014.5
37018	44.06	39.04	2044.96	1229.20	1012.8
17030	41.17	36.20	1857.4	880.30	1015.7
17370	36.35	36.10	1907.68	330.18	1011.3
17260	37.05	37.22	2002.22	423.40	1012.4
17200	38.26	38.05	2058.94	572.18	1012.1
34858	45.55	43.21	2330.76	1451.24	1013.5
37054	44.13	43.06	2354.7	1297.52	1013.9
17098	40.36	43.05	2448.77	888.16	1010.7

1.2 MAP PROJECTION

For meteorological analysis and its application like numerical weather prediction and viewing data, one needs representation of the earth surface on a plane surface. For these purposes it is preferred to make map projection of the spherical coordinates of points on earth surface to Cartesian coordinates on a plane surface.

The map projections most common used in meteorology are the Mercator, polar stereographic and Lambert conformal. The Lambert conformal is often used for map representation in middle-latitudes, polar stereographic is often preferred for map analysis in middle and high latitude and Mercator projection is often used for low-latitude (tropical latitudes) studies. The choice of particular projection in mapping for meteorology depends largely on the geographical position of the area involved.

1.2.1 GRID STRUCTURE

The points of network or grid points that are normally used for meteorological applications in the finite-difference method are not separated by uniform angular increments of latitude or longitude, but are separated by a uniform Cartesian-coordinate system on a map projection of the earth's surface.

The grids are generally in square form with sides $\Delta x = \Delta y$, and with maximum grid in x-axis as $i_{\max}$ and in y-axis as $j_{\max}$, as shown in Figure 1.2. The point $x = 0$, $y = 0$ is defined as the lower left corner with $i = 1$, $j = 1$. The array of grid points are regularly distributed within the study area where the observation points, i. e., meteorological stations are irregularly scattered within these grid points of network. In the whole rectangle, the grid points must be centered at latitude ϕ_0 and longitude λ_0 with $X = 0$ and $Y = 0$, (Anthes, Hsie, Kuo, 1987).

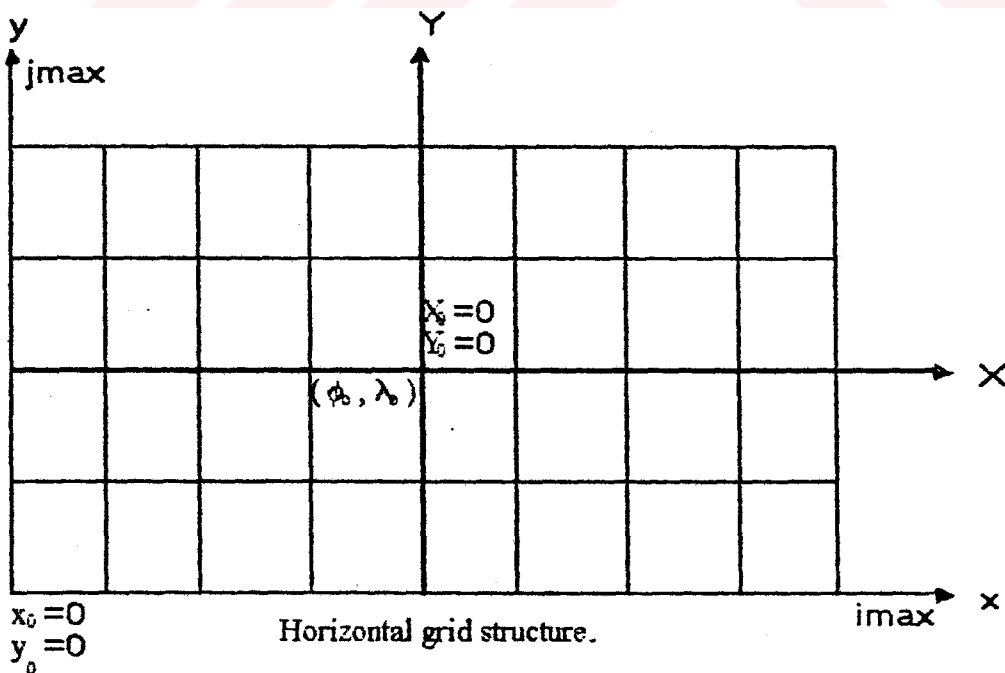


Figure 1.2. Network and grid points structure.

Any variable can be defined at the network by the following relationship

$$x(i, j) = (i - 1) \Delta x \quad (1.1)$$

$$y(i, j) = (j - 1) \Delta y \quad (1.2)$$

where $i = 1, 2, 3, \dots, i_{\max}$

$j = 1, 2, 3, \dots, j_{\max}$

Furthermore the relationships between (x, y) and (X, Y) are given by

$$x = X + \frac{i_{\max} - 1}{2} \Delta x \quad (1.3)$$

$$y = Y + \frac{j_{\max} - 1}{2} \Delta y \quad (1.4)$$

1.2.2 POLAR STEREOGRAPHIC PROJECTION

In this research, polar stereographic projection is used for study area because it is valid for middle and high latitudes. In the case of limited area analysis it can be more convenient to define a map origin at longitude λ_0 and standard parallel latitude ϕ_0 corresponding to the point with $X = 0$ and $Y = 0$.

The relationship, between the map location coordinates (X, Y) and latitude ϕ and longitude λ is given by Thiebaux and Pedder (1987) as (see Figure 1.3.)

$$X = a m \cos \phi \sin(\lambda - \lambda_0) \quad (1.5)$$

$$Y = a [\cos \phi_0 - m \cos \phi \cos (\lambda - \lambda_0)] \quad (1.6)$$

$$m = \frac{1 + \sin \phi_0}{1 + \sin \phi} \quad (1.7)$$

where m - is **map-scale factor** which is defined as the ratio of the distance on the map (on plane surface) to the corresponding distance on the sphere.

- ϕ any latitude (negative for south latitude)
- λ any longitude (negative for west longitude)
- a radius of the earth

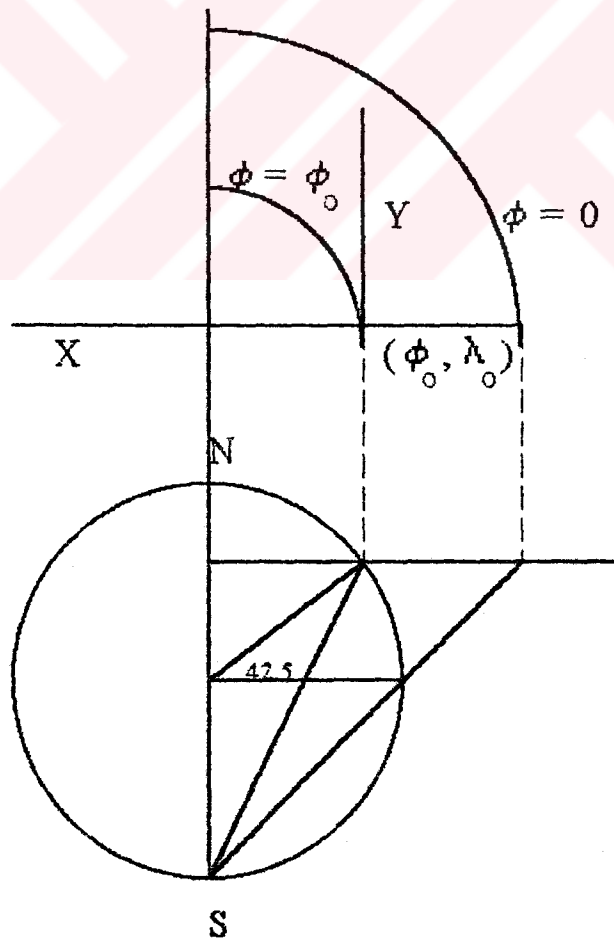


Figure 1.3. Polar stereographic projection with standard parallel 42.5° N.

CHAPTER 2

SPATIAL VARIATION

2.1 GENERAL

The Spatial Variation which is also referred to as "Regionalized" Variables of any meteorological variable is a function describing natural phenomena that have geographical distribution such as temperature, air pollution, rain, etc. Furthermore, it has continuity from point to point but the changes in the variable are complex, to the extent that it can not be described by any function, (Davis, 1986). Also it can be define as "it is any numerical function with a spatial distribution that varies from one place to another with apparent continuity whose changes can not be represented by any workable function", (Olea, 1974).

Weather maps are two-dimensional representations of meteorological variables for synoptic analysis or for viewing data. These maps are representations of the spatially continuous meteorological variables at discrete points where the variability is sampled.

Meteorological stations are the locations for the data measurements. Between these data stations, logically, there is a spatial continuity. For instance, two close stations to each other are more likely to have similar values than two that are far apart. A quick look at observation data map, indicates that the values do not appear to be randomly located, but rather systematically low values tend to be

near other low values and high values tend to be near other high values, (Isaaks and Srivastava, 1989).

The spatial variation similar to the time variation in some properties, indicates a correlation between variables at adjacent points, and also there are some important difference. In temporal variation the distance between successive points is constant time interval, however in spatial variation there are two-dimensional coordinates for distribution of data and the distance between points are not necessarily equal intervals as they are in time variation. Also there are no exact periodic fluctuations in space like in time except, that the variabilities repeat themselves after one revolution of earth's circumference, (Panofsky and Brier, 1968).

The literature is full of various statistical tools using to describe the relationship between two variables so as to know spatial continuity like variance techniques and the classical autocorrelation methods. Nevertheless, these methods are not helpful to account directly for the spatial dependence or for the variability in term of sample positions.

2.2 CUMULATIVE SEMIVARIOGRAM (CSV)

The cumulative semivariogram (CSV) is a new technique in modeling of meteorological data which are commonly observed at irregular meteorological stations. The basis of this technique is proposed in detail by (Sen, 1989).

The CSV is defined as "The summation of half-squared-difference which are ranked in ascending order of distance" and it can be defined mathematically as:

$$\gamma_{c_k} = \sum_{k=1}^{m_c} \Delta Z_{c_k} \quad (2.1)$$

in which ΔZ_{c_k} indicates the half-squared difference at k-th order in an ordered distance arrangement where superscript k indicates the rank and Z_c any meteorological variable corresponding to rank k, (Sen, 1993).

It is used as a method for determining various properties such as the range of influence; to find more information about homogeneity; continuity; dependence; independence and correlation. The following advantages make the CSV attractive in practical application.

- a) The CSV is a nondecreasing function.
- b) The slope of CSV is an indicator of regional dependence between pairs of spatial points separated by the distance.
- c) The CSV may be used for irregular distribution of data within study area.

2.2.1 PRACTICAL CONSTRUCTION OF CSV

In order to calculate cumulative semivariogram for modeling meteorological data one must apply the following steps:

- a) Compute the scalar distance between all possible two pairs of observation station by using the definition of distance from analytical geometry as

$$D_{c_i} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \quad (2.2)$$

where $i \neq j$ and

$k = 1, 2, 3, \dots, m_c$

$i = 1, 2, 3, \dots, n$

$$j = 1, 2, 3, \dots, n$$

Herein D_{c_i} is the scalar distance between any two stations with coordinates (x_i, y_i) and coordinates (x_j, y_j) , respectively.

The number of distances among n observation stations is m_c and it is given as :

$$m_c = \frac{n(n-1)}{2} \quad (2.3)$$

For example if $n = 5$ then there are $m_c = 10$ different half-squared difference and distance values.

- b) Calculate the half-squared differences, between every pairs of meteorological data values at all observation stations. Hence, for each distance D_{c_i} , a corresponding half-squared difference will be calculated as:

$$\Delta Z_{c_i} = \frac{1}{2} (Z_i - Z_j)^2 \quad (2.4)$$

where $i \neq j$.

- c) Sort the distances in ascending numerical order while making the corresponding rearrangement of the half-squared difference ΔZ_{c_k} , herein the subscript k also indicates the degree of sorting. For instance ΔZ_{c_2} denotes the second smallest half-squared difference.
- d) Find the cumulative summation of ΔZ_{c_k} after sorting then the CSV, can be written mathematically as in equation 2.1.

- e) Plot the ordered distance in horizontal axis and CSV values in vertical axis and then we get the CSV diagram.

The execution of these five steps leads to desired CSV which is exemplified in Figure 2.1. Such a CSV shows the general dependence structure of regionalized variable without any detail around each point.

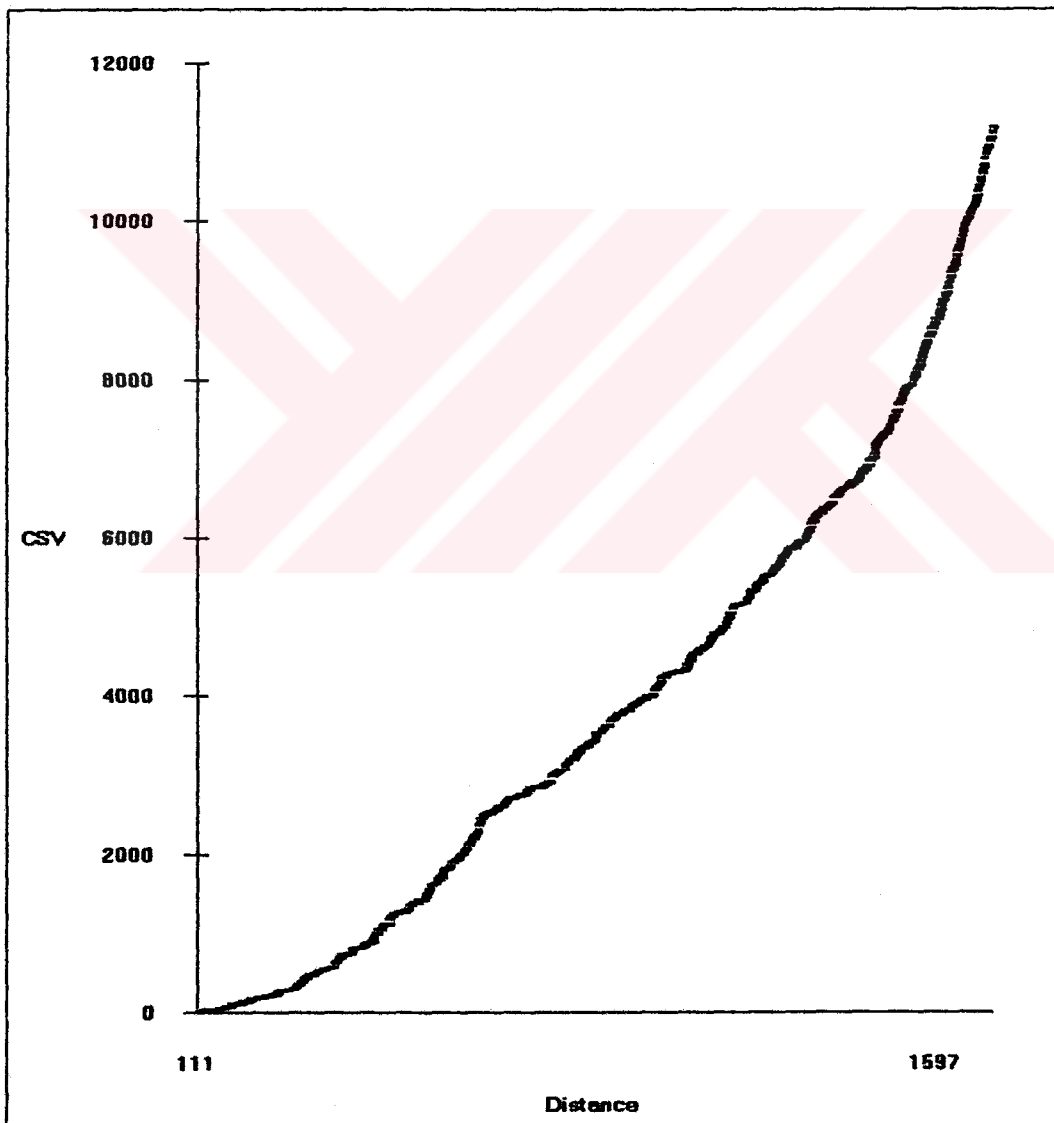


Figure 2.1. Sample CSV scatter diagram.

2.3 POINT CUMULATIVE SEMIVARIOGRAM (POINT CSV)

The CSV as explained in the previous section is not convenient for representing regional variability changes around every single station within any study area. It gives rather a constant variability all over the region. However, it is well known in meteorology that such small scale variations appear together with large and medium (meso) scales. This is an indicator that CSV concept does not have flexibility to cope with scale changes.

This drawback of CSV gives to the author an idea of looking for more suitable semivariogram which can be employed in meteorology. The basic idea is to look for a method which is expected to model spatial variabilities around individual stations. Finally, with the modification of CVS the author suggested herein **point cumulative semivariogram (point CSV)** concept.

Hence, it is possible to define point CSV as a measure of variability around any single station by considering other stations' effects on this station which will be referred here onward as the **reference point**.

Also point CSV can be defined as "The summation of half-square-difference between the reference point and other stations around it, which are ranked in ascending order of distance." it can be defined mathematically as:

$$\gamma_{p_i} = \sum_{k=1}^{m_p} \Delta Z_{p_i} \quad (2.5)$$

where γ_{p_i} indicates the point CSV value.

2.3.1 PRACTICAL CONSTRUCTION OF POINT CSV

The point CSV can be obtained by the following steps:

- a) Calculate the scalar distance, D_R between reference point (see Figure 2.2)with coordinates (x_r, y_r) and another surrounding stations, with coordinates (x_i, y_i) , can be written as:

$$D_{pi} = \sqrt{(x_i - x_r)^2 + (y_i - y_r)^2} \quad (2.6)$$

where $r \neq i$ and

$$k = 1, 2, 3, \dots, m_p$$

$$i = 1, 2, 3, \dots, n$$

The number of distances between the reference station and n observation stations is denoted by m_p which can be obtained as:

$$m_p = (n - 1) \quad (2.7)$$

For instance, if the number of stations in study area is $n=50$ then $m_p = 49$ it means that for this reference point 49 half-squared difference values must be calculated.

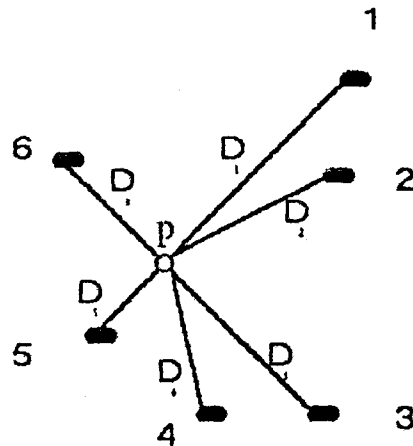


Figure 2.2. Reference point and surrounding stations

- b) Calculate the-half-squared differences, ΔZ_{pi} of meteorological data between reference point and all other stations in the study area.

$$\Delta Z_{pi} = \frac{1}{2} (Z_i - Z_r)^2 \quad (2.8)$$

where $r \neq i$.

- c) Sort the distance D_k in ascending numerical order while making the corresponding rearrangement of the half-squared difference ΔZ_{pi} , where the subscript k also indicates the degree of sorting.
- d) Find the cumulative summation of ΔZ_{pi} after sorting then the point CSV can be written mathematically as in equation 2.5.
- e) Plot the ordered distance in horizontal axis and point CSV values in vertical axis and then we get the point CSV diagram. Which is rather similar to the ordinary CSV as shown in Figure 2.1. However, the interpretation for the point CSV will be valid for the reference point and not for the whole region as it is in the case of CSV.

2.3.2 POINT CSV MODELLING

The point CSV is known only at discrete points representing distance "D"; in practice, point CSV may be required for any distance, and therefore, the discrete experimental point CSV must be modelled by a continuous function that can be evaluated for any desired distance.

Although there are several models to represent point CSV by continuous function such as linear, power, exponential, logarithmic, parabolic, cubic etc. functions, the basic

modeling form of this research has been adapted as "power law" throughout for point CSV. The main reason of finding the function of theoretical point CSV is for determining the radius of influence which plays a major role in the objective analysis.

In general the power model has the following mathematical expression :

$$\gamma_p = \alpha D^\beta \quad (2.9)$$

n which γ_p represents the theoretical point CSV value and D is the distance, α and β are the model parameters. These parameters must be estimated from regional meteorological data by means of point CSV and the least squares technique so as to find the best power function fitting to the point CSV scatter diagram.

CHAPTER 3

OBJECTIVE ANALYSIS

3.1 GENERAL

In the analysis of weather data, it is often necessary to transform the data from nonuniformly distributed observation sites to a rectangular grid suitable for numerical calculations. The transformation is accomplished by some form of interpolation and is referred to as Objective Analysis.

Subsequently, one can define objective analysis as "the procedure of transforming data observations at irregularly spaced points onto points of a regularly spaced grid". There are a lot of analysis methods that have been used in meteorology to interpolate data from stations to the grid points, as Schlatter (1988) classified these methods into the following types :

- a) Surface fitting methods :
 - i. Polynomial interpolation, (Panofsky, 1949)
 - ii. Orthogonal polynomials, (Dixon, 1969, 1976)
 - iii. Splines, (Fritsch, 1971)
 - iv. Spectral approaches, (Flattery, 1970)
- b) Empirical linear interpolation :
 - i. Iterative successive correction, (Cressman, 1959)
 - ii. Barnes analysis, (Barnes, 1964)
- c) Statistical objective analysis :
 - i. Optimal interpolation, (Gandin, 1963)
 - ii. Covariance models for atmospheric variable, (Buell, 1958)
 - iii. Adaptive filtering, (Kalman, 1960)

d) Variational techniques

- i. Incorporation of dynamic constraints, (Sasaki, 1958)
- ii. Fitting models to data at different times, (Ledimet and Talagrand, 1986)

All of these methods are use for different purposes by various researchers in the meteorology domain. It is not within the scope of this thesis to discuss each one of these methods in detail because for those interested the proper references are given above. However, the main purpose of the thesis is to develop a new technique and to compare it with some of the powerful available methods such as successive correction method SCM.

3.2 SUCCESSIVE CORRECTION METHOD

An important class of objective analysis techniques known as "successive correction method", (SCM) was first described by Bergthorsson and Doos (1955). Later, it was introduced into operational meteorology by Cressman (1959). Though replaced by multivariate statistical techniques as the operational interpolation method in many numerical forecasting models, the SCM's are still widely used for gridding meteorological data, because gridded fields can be produced more economically by the SCM, (Achtemeier, 1989).

The basic concept of SCM is to correct the background (guess) field iteratively during several analysis which are called as scan. In each analysis scan, the corrections are calculated, the result of SCM may be expressed simply as an initial background field plus a weighted sum of observed increments, which are a form identical to that used in statistical interpolation. Thus by interpolation of the deviation of the observed values from the background field one can write the following equation :

$$Z_{i,j}^2 = Z_{i,j}^1 + \frac{1}{N} \sum_{k=1}^N W_k (Z_{ok} - Z_k^1) \quad (3.1)$$

where

$i=1, \dots, \text{imax}$; $j=1, \dots, \text{jmax}$; $k=1, \dots, N$

$Z_{i,j}^2$ is estimated value at grid point,

$Z_{i,j}^1$ is the background field value,

Z_{ok} is the observed value at observation station,

Z_k^1 is the interpolation first guess at observation station,

N is the number of stations in the influence region,

W_k is weighting factor given as (Thiebaut, and Pedder, 1987),

N is the number of station in the influence area.

$$W_k = \begin{cases} \left[\frac{R^2 - D^2}{R^2 + D^2} \right]^\eta & D < R \\ 0 & D \geq R \end{cases} \quad (3.2)$$

where D is the distance between observation station and the grid point, and R influence radius, which decreases with each iteration. However, this weighting factor can be improved by taking power of η on the right hand side as mentioned by Thiebaut and Pedder (1987). The significance of η is for smoothing rather highly variable data at different stations.

3.3 MODIFICATION OF SCM

This study presents a modification of the successive correction method (MSCM) to improve upon the best analysis obtainable by the technique. Some of the reasons for using the SCM as a reference in this study are:

- a) To combine that the point CSV in order to find objective influence region around one single point.
- b) The SCM is rather straight forward and easy.
- c) It does not account for the distribution of observations relative to each other.

By using point CSV it is possible to determine correlation between any individual point and surrounding stations, as shown in Figure 3.1. It can be noticed that the point CSV has curvature portion for small range of distance. Such a curvature implies the effect of correlation. It is interesting to notice also in the same figure as it will be seen in any point CSV graph in Appendix-A that consistently all of the point CSV's have curvature portion followed by almost straight line at large distance. The distance of point at which curvature conversion takes place to a straight line is the basic definition of the radius of influence as it is adopted in this research.

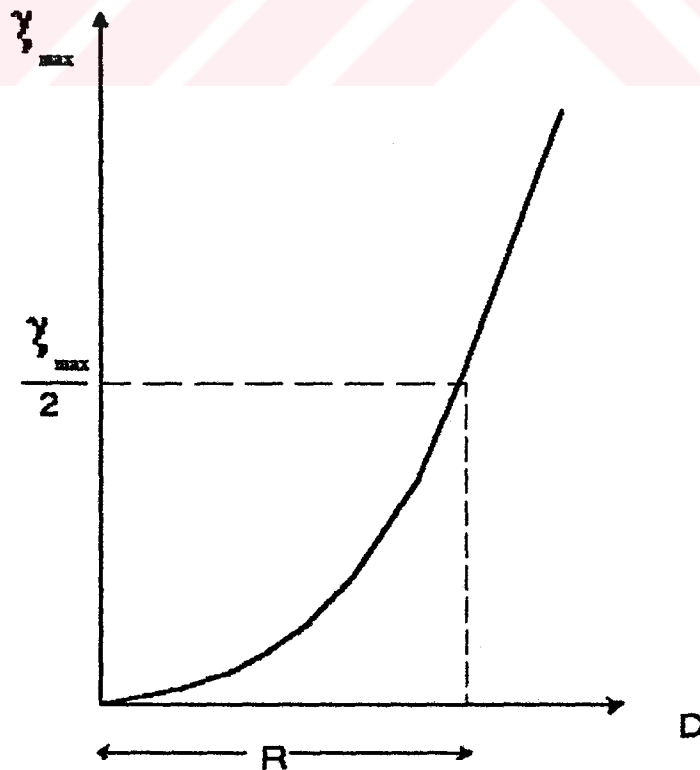


Figure 3.1. Point CSV Model.

In fact, such a range corresponds to the influence of radius in objective analysis. After this range, the point CSV's converge to straight line at large distance. The initial curvature implies that observation stations along this curvature have regional dependence which weakens towards the end of curvature distance.

In order to define the transition point from curvature to straight line the assumption made in this work is that half of the maximum point CSV corresponding on the distance axis to the radius of influence R as shown in Figure 3.1.

Substitution of $\frac{\gamma_{pmax}}{2}$ and R into equation (2.9) instead of γ_p and D , respectively, yields

$$\frac{\gamma_{pmax}}{2} = \alpha R^\beta \quad (3.3)$$

By taking logarithm of both sides one can obtain

$$\log\left\{\frac{\gamma_{pmax}}{2}\right\} = \log \alpha + \beta \log R \quad (3.4)$$

or arranging this expression one it is possible to

$$\frac{1}{\beta} \log\left\{\frac{\gamma_{pmax}}{2}\right\} - \frac{1}{\beta} \log \alpha = \log R \quad (3.5)$$

then the result becomes

$$R = \left\{\frac{\gamma_{pmax}}{2\alpha}\right\}^{\frac{1}{\beta}} \quad (3.6)$$

3.3.1 PRACTICAL CONSTRUCTION OF MSCM

It is worthy to mention at this stage that Cressman method needs more than two scanings whereas its extension as Barnes method there are exactly two scanings (Schlatter, 1988). However, the method proposed here as the MSCM has only one scanning operation, and therefore, it provides a great economy in scanning procedure. The reason of having one scanning is due to the fact that the point CSV's yield single radius of influence at each station contrary to SCM which can not define radius of influence in a unique way but there are subjectivities.

The MSCM needs only one scan and it consists of the following steps for successful application :

- a) Calculation of radius of influence at every station by point CSV.
- b) Interpolation of influence radius at every grid point, from irregular data points.
- c) Interpolation of a background (first guess only) field to the location of observation, .
- d) Evaluation of a correction (observation minus background) at the location of each observation.
- e) Accumulation at each grid point of a weighted sum of correction from observation stations.
- f) Evaluation of an estimation value at each grid point, by adding the weighted sum of correction to the background field.

CHAPTER 4

RESULT AND DISCUSSIONS

4.1 ANALYSIS OF POINT CSV

From 47 observation stations , it is possible to calculate sample point CSV at every single station, and the result as point CSV graphs are given in Appendix A. Furthermore, the theoretical point CSV model are found by fitting power functions which represent the relationship between the point CSV values and the distance.

The mathematical form of each power law is given in Table 4.1. as model parameters α and β . The reason of finding the theoretical point CSV is for determining the radius of influence. Table 4.1 includes the point CSV parameters and radius of influence for each station.

In order to give some idea to the reader Figure 4.1. for station number 15480 is produced, herein. It is obvious that this is one of the best match of theoretical point CSV with the sample point CSV according to power model.

In this figure like any other one in general, there are two distinctive portions, one with big curvature and the other with small curvature. The former means strong regional correlation whereas decrease in the curvature implies decrease in the dependence.

Furthermore, for this station since the deviations from the theoretical point CSV are small one can conclude that at this station the pressure phenomenon is rather homogeneous. However, as one can see in Figure 4.2. For

instance, the point CSV at station number 17026 has heterogeneous structure.

Another case appears in station number 17248 as shown here in Figure 4.3. It is more or less in the form of straight line, i.e. the curvature is negligibly small which implies that the pressure phenomenon effect on this station from other stations is independent. In other words, in such a situation one needs larger areas which means more station number than usual to obtain reliable results.

Finally, Figure 4.4. shows isolines of computed influence of radius for surface pressure chart in the study area. From the figure one can notice that in general, the minimum value of influence of radius is located approximately at center of study area. It increases from the center until reaches a maximum at the corners of the chart.

Table 4.1 Power model parameters.

Station no.	α	β	R(km)
12843	4.25×10^{-5}	1.84	2500
12982	1.74×10^{-5}	2.06	2050
13242	2.04×10^{-4}	1.65	2123
13353	2.93×10^{-5}	1.99	2043
11968	2.85×10^{-3}	1.37	1509
15004	3.37×10^{-6}	2.29	1841
12882	2.56×10^{-4}	1.64	2546
15230	9.38×10^{-1}	3.14	1518
13275	4.49×10^{-7}	2.55	1814
15511	4.86×10^{-6}	2.32	1493
15614	6.62×10^{-5}	1.92	1331
13583	9.27×10^{-4}	1.59	1075
16643	2.52×10^{-5}	2.17	1471
16682	1.58×10^{-6}	2.42	1593

Table 4.1 Power model parameters.(Continue)

16730	2.16×10^{-6}	2.44	1179
16734	2.29×10^{-7}	2.72	1520
33587	2.65×10^{-9}	3.36	1243
15480	3.16×10^{-10}	3.88	991
17050	1.98×10^{-9}	3.54	1023
17059	2.27×10^{-8}	3.24	888
17110	1.02×10^{-6}	2.64	1079
17150	5.19×10^{-1}	2.39	937
17188	1.30×10^{-4}	1.94	845
17292	4.86×10^{-4}	1.86	845
17218	4.33×10^{-5}	2.08	924
33791	2.16×10^{-7}	2.80	1055
33837	1.79×10^{-8}	3.16	1119
33946	1.67×10^{-8}	3.24	906
17022	1.08×10^{-8}	3.48	791
17024	6.86×10^{-8}	2.55	788
17026	1.39×10^{-4}	1.98	768
17128	7.12×10^{-7}	2.81	777
17124	6.19×10^{-5}	2.16	797
17190	1.98×10^{-4}	1.90	817
17244	4.87×10^{-4}	1.76	804
17240	4.27×10^{-4}	1.80	857
17248	4.04×10^{-2}	1.11	825
17330	1.00×10^{-3}	1.81	1077
34824	4.77×10^{-7}	2.73	1154
37018	1.13×10^{-6}	2.70	1171
17030	2.72×10^{-3}	1.51	819
17370	3.32×10^{-5}	2.30	1195
17260	4.44×10^{-8}	2.52	1224
17200	1.16×10^{-7}	3.06	1195
34858	1.11×10^{-9}	3.52	1498
37054	3.71×10^{-8}	3.83	1460
17098	5.64×10^{-8}	3.12	1519

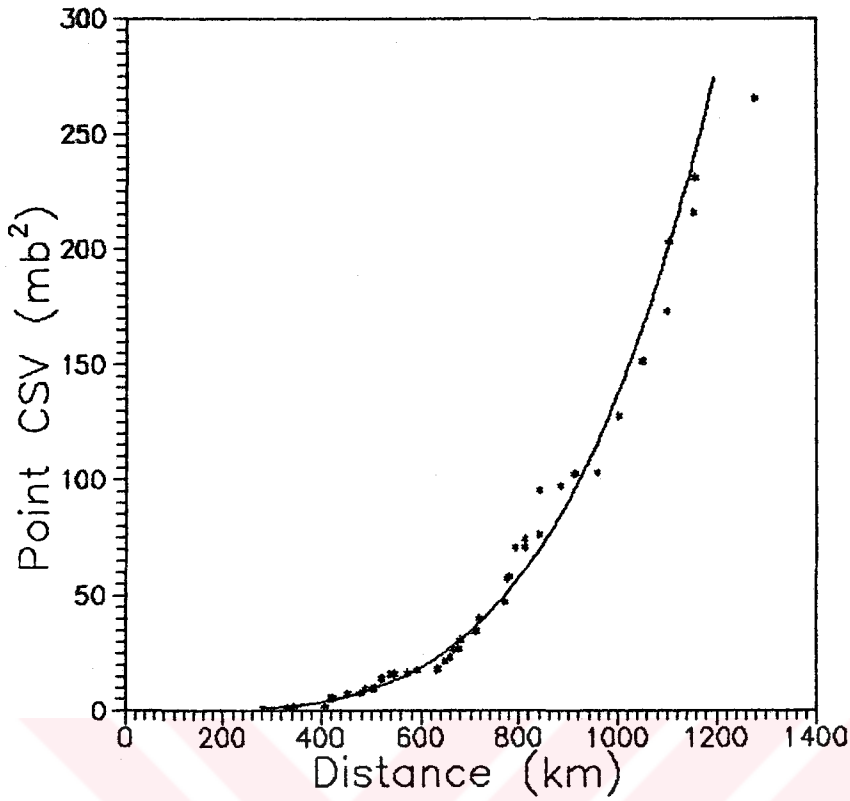


Figure 4.1 Point CSV for station NO. 15480.

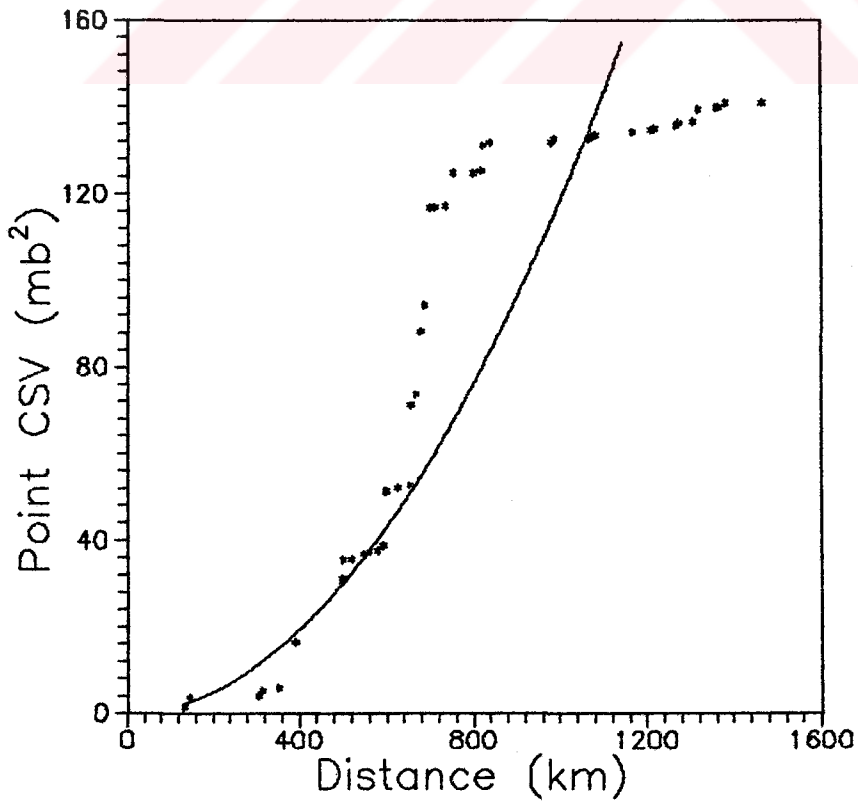


Figure 4.2 Point CSV for station no. 17026.

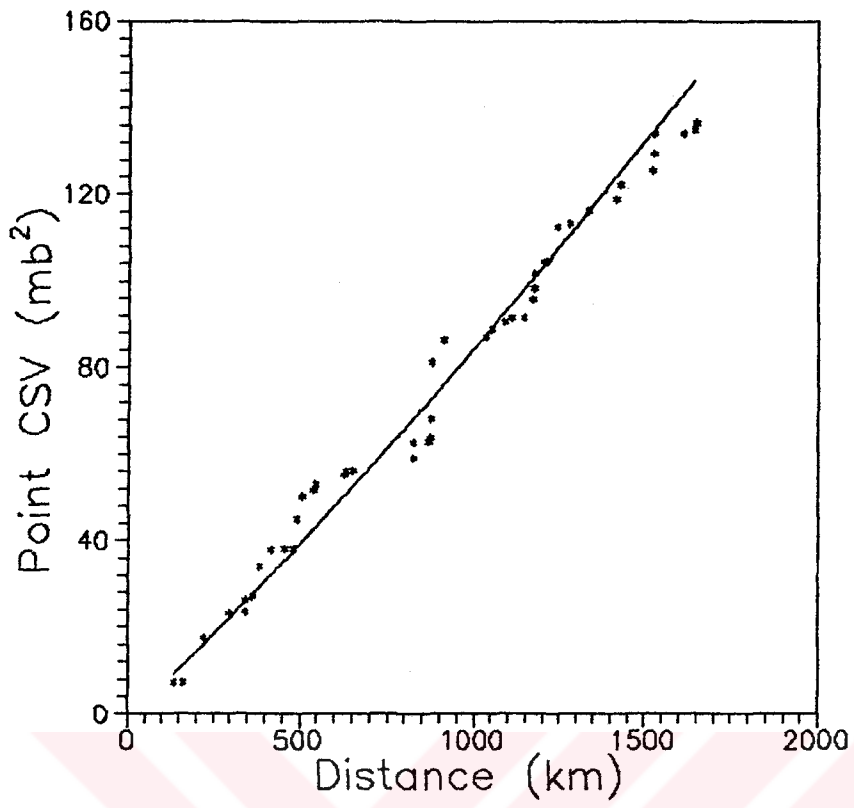


Figure 4.3 Point CSV for station no. 17248.

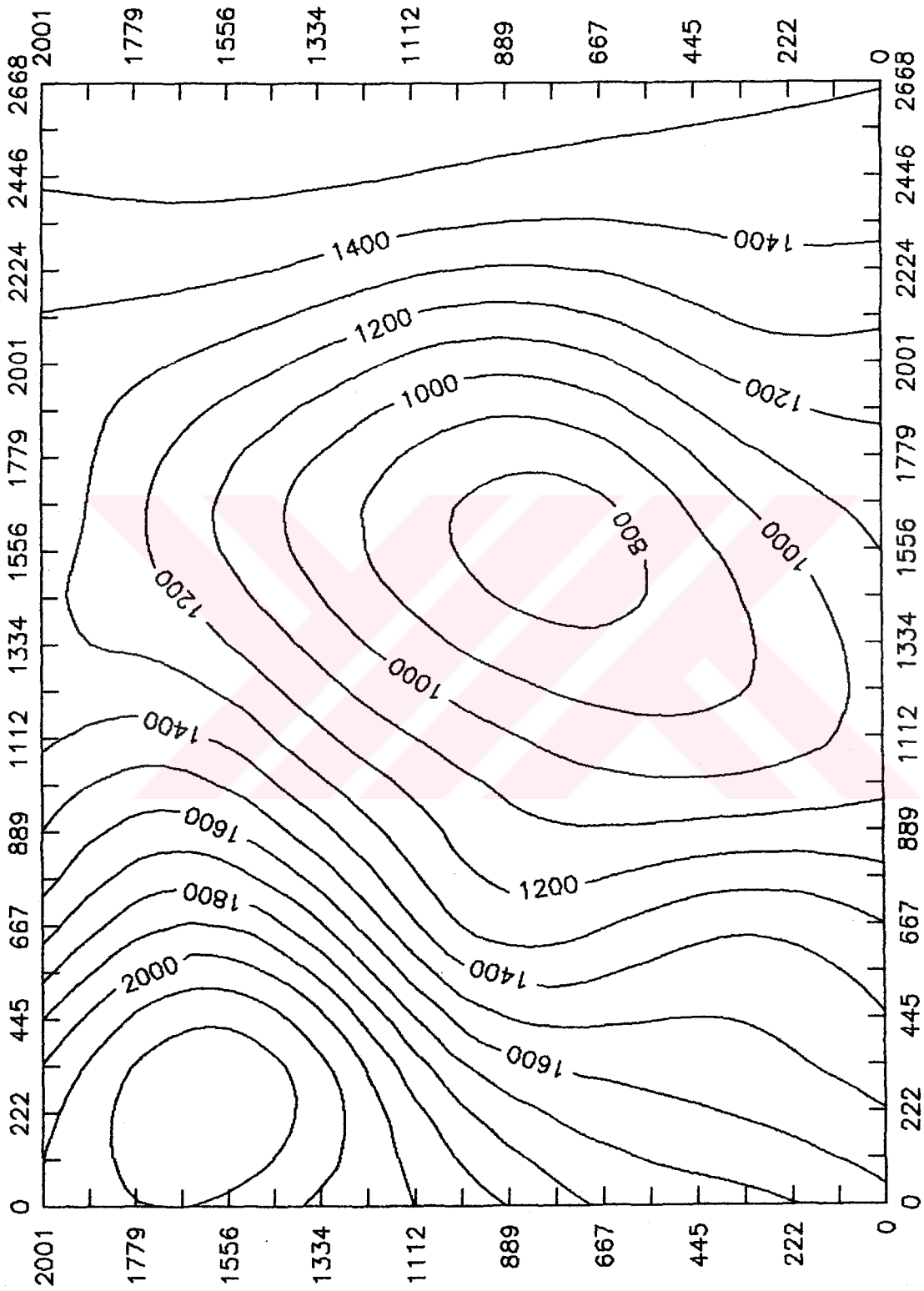


Figure 4.4 Isolines of the radius of influence.

4.2 COMPARISON BETWEEN SCM AND MSCM

The accuracy of two different methods used in objective analysis in this study, was investigated with the help of numerical experiments from the surrounding stations and in comparison of the interpolated values with the observed ones, (Gandin, 1965).

Similarly **Cross Validation** technique allows us to compare estimated and true values using only the information available in our observed data, (Isaaks and Srivastava, 1989).

In a cross validation technique, the interpolation method is tested at the observation station, the observed value at particular station is temporarily discarded from the surrounding stations. The value at the same station is then estimated using the remaining other stations, once the estimate is calculated one can compare it with the true value that was initially removed from the station. This procedure is repeated for all available stations, with comparison of observed, interpolated and actual by using visual and statistical tools.

The analysis of surface pressure has been carried out for 1200 GMT on 19 June 1990 by using the two methods and the results are shown in Figures 4.5 and 4.6 There are 47 observation stations in the study area with average spacing among stations as 337 km and average surface pressure 1016.54 mb, The statistical parameters of the comparison between various method estimates and of the true values are summarized in Table 4.2.

In general the difference between the average estimate from the two methods and the true average, reflects a tendency toward overestimation or underestimation. However, in this study the two methods have a slight tendency toward underestimation as seen from the table.

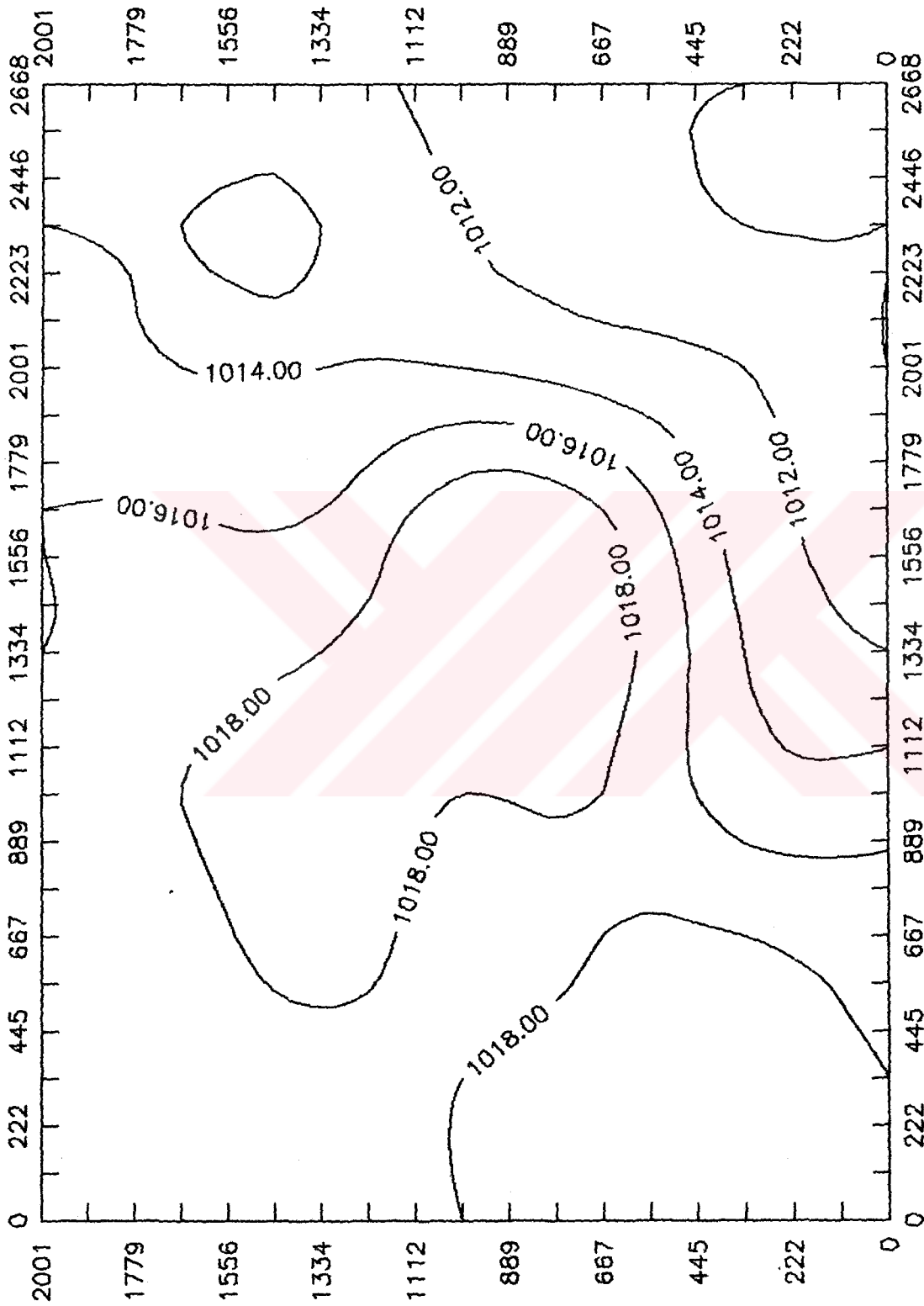


Figure 4.5 Analysis of surface pressure with 5CM.

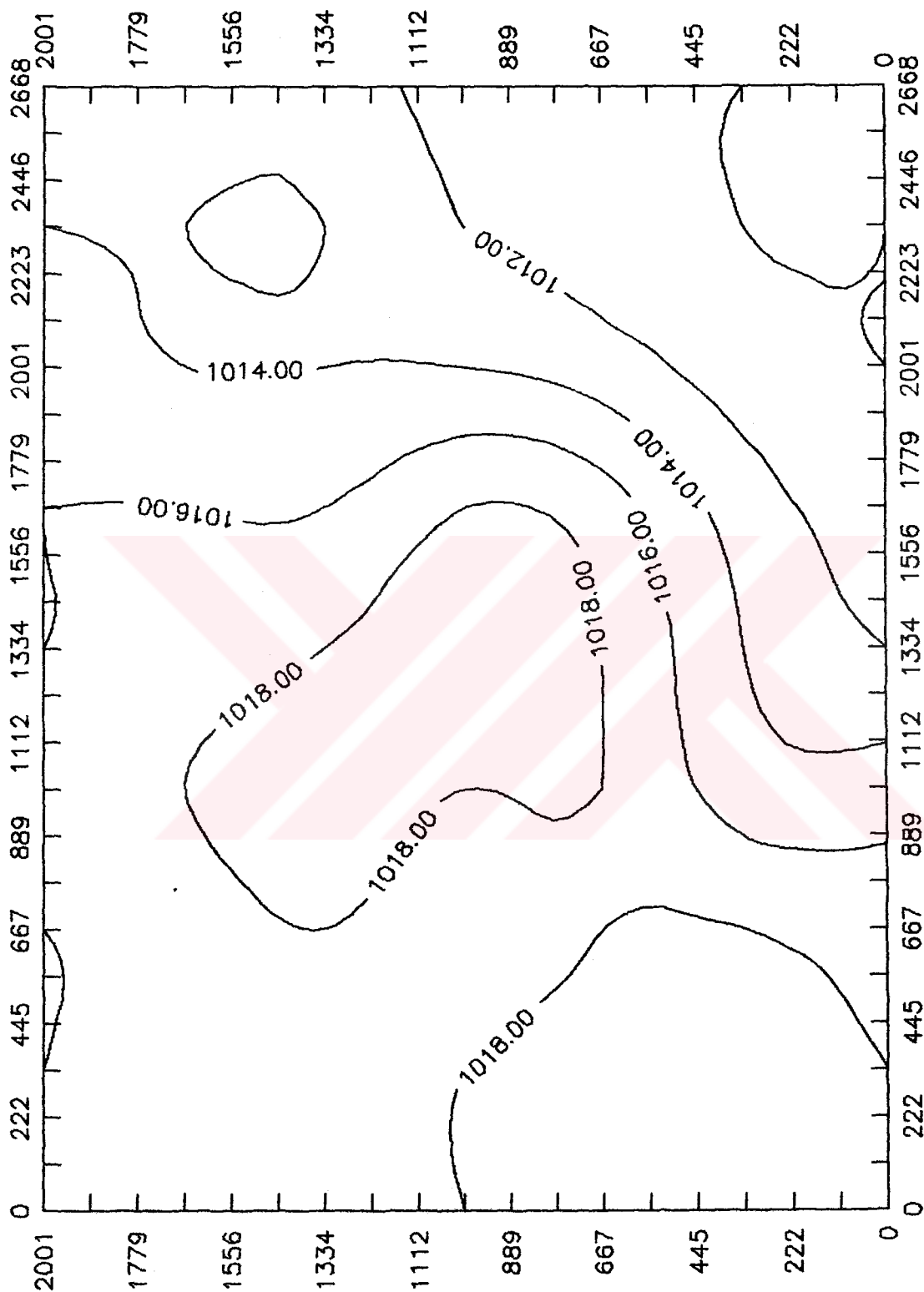


Figure 4.6 Analysis of surface pressure with MSCM.

Table 4.2 comparison of estimates calculated by the SCM and MSCM with the true values.

Variable	True value	SCM	MSCM
Sample size	47	47	47
Average	1016.54	1016.53	1016.43
Median	1017.10	1017.00	1017.00
Mode	1017.10	1018.00	1018.00
Variance	5.37	4.47	4.38
Standard dev.	2.33	2.11	2.09
Standard error.	0.34	0.31	0.30
Minimum	1010.70	1011.00	1011
Maximum	1019.80	1019.00	1019.00
Range	9.10	8.00	8.00
Corr.coeff	-----	0.94	0.95

Comparisons of the true values standard deviation with the two methods indicate that MSCM has less variability than the other technique. However, SCM standard deviation is rather closer to the true values standard deviation. As a result of such a comparison it is obvious that MSCM gives better results, because SCM has bigger variability.

This fact is also confirmed by the correlation coefficient. The SCM estimates have correlation coefficient which is comparatively slightly less than the MSCM correlation coefficient.

In order to compare the accuracy of these two different methods two types of experiments were performed :

- a) the network of stations was taken to be dense.
- b) the network of stations was taken to be sparse.

The results of these experiments are shown in Figure 4.7 as the change of Mean Square Error (MSE) with the number of stations.

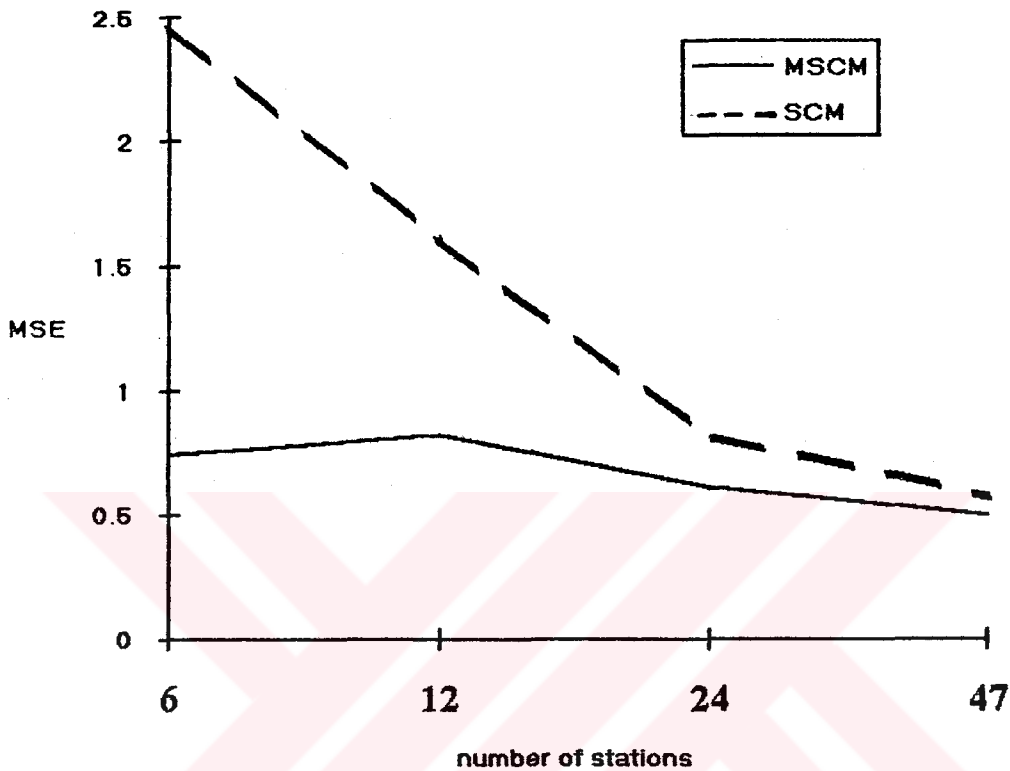


Figure 4.7 MSE variation with station number.

In the first case, network of the two methods gave very close results. It is obvious from this figure that as the number of stations increase the MSE of two methods merge together asymptotically for large station numbers. However, in the second case MSCM has an overwhelmingly less MSE than SCM which confirms the validity of MSCM especially for sparse station densities. Figure 4.7 shows very clearly that as the number of stations increase then the two methods approaches each other asymptotically one can also notice in the same figure that although the difference between MSE's of the two methods is rather small, but for station numbers less than almost 20 this difference becomes exponentially large.

It is recommended herein that for small number of stations without any hesitation MSCM is preferable. The estimates of the accuracy of the different methods used for the sparse network of stations are given in Tables 4.3.

Table 4.3. Comparaison of two methods by using MSE.

Methods	No. of stations	Average spacing between stations	MSE
SCM	47	337.06	0.57
MSCM	47	337.06	0.50
SCM	24	471.06	0.82
MSCM	24	471.06	0.61
SCM	12	667.06	1.61
MSCM	12	667.06	0.82
SCM	6	943.37	2.46
MSCM	6	943.37	0.74

All of the calculation needed in this research work are carried out by computer programs in Quick Basic Version 4.5 by the author and they are provided in the form of Appendix B at the end of this thesis.

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APPENDIX A

(SUPPLEMENTARY FIGURES)



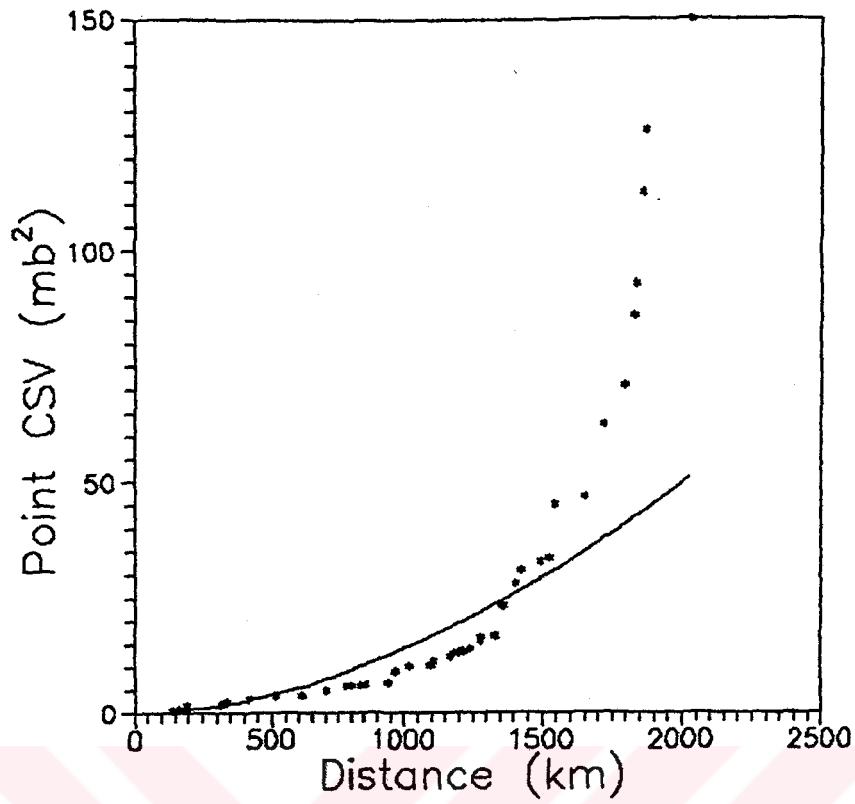


Figure A.1 Point CSV for station no. 12843.

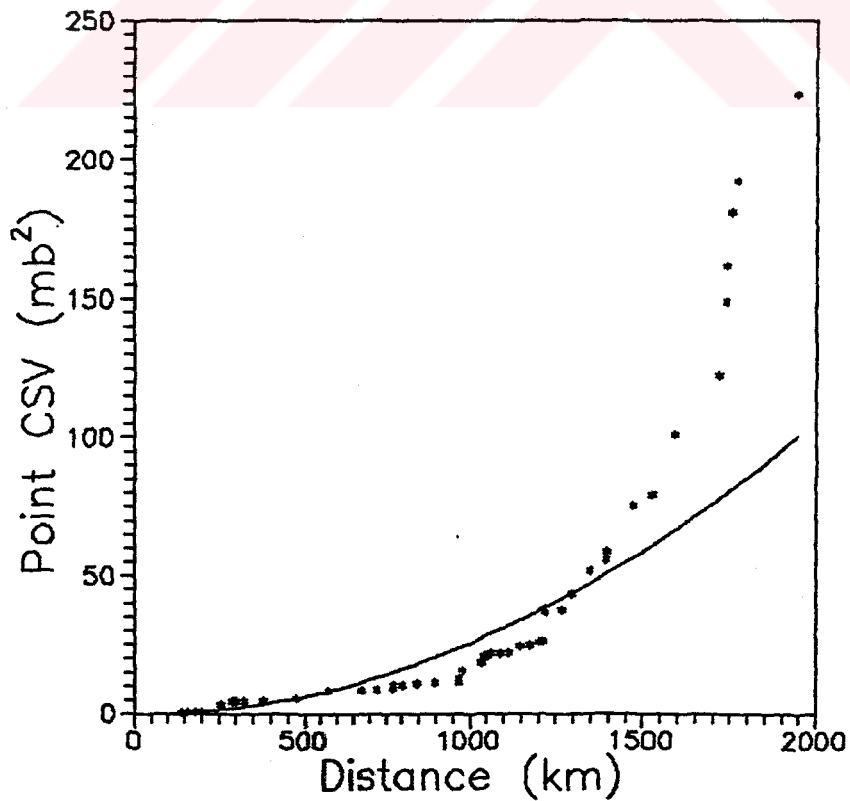


Figure A.2. Point CSV for station no. 12982.

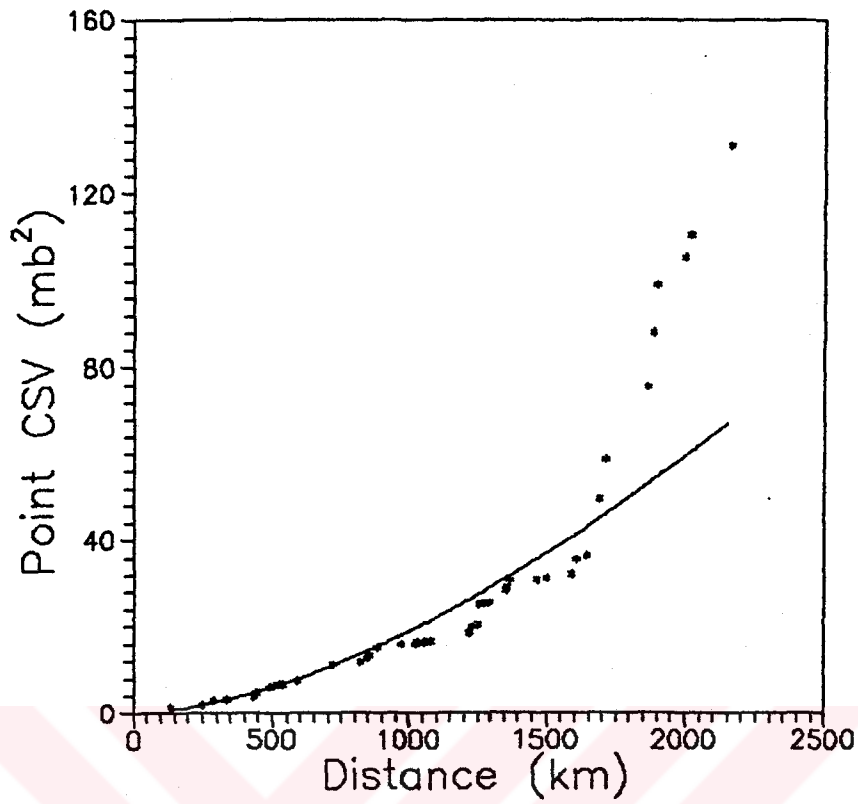


Figure A.3. Point CSV for station no. 13242.

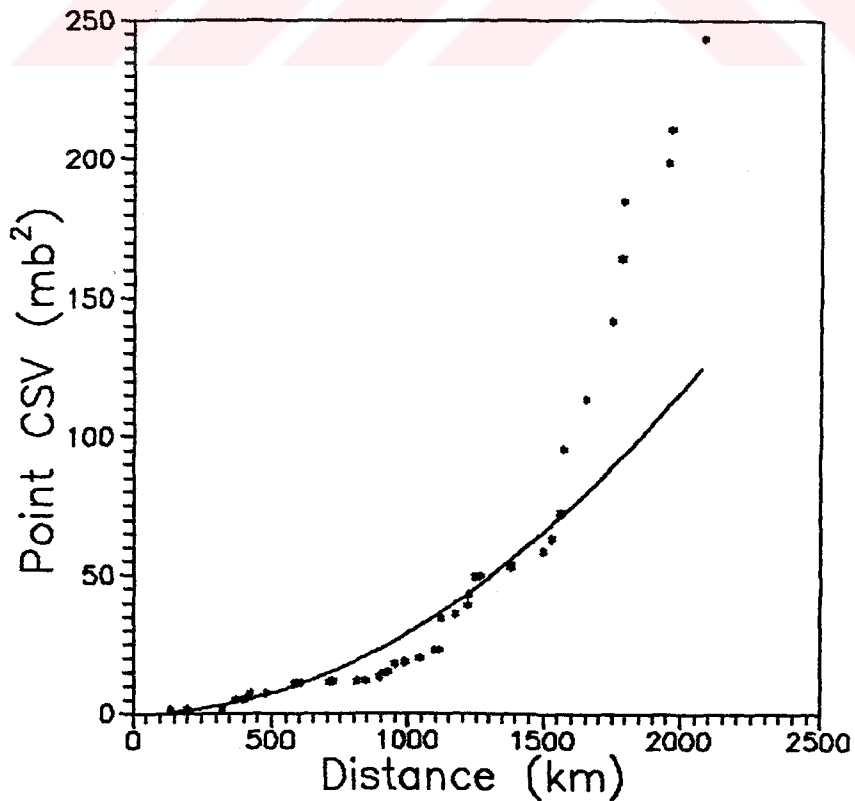


Figure A.4. Point CSV for station no. 13353.

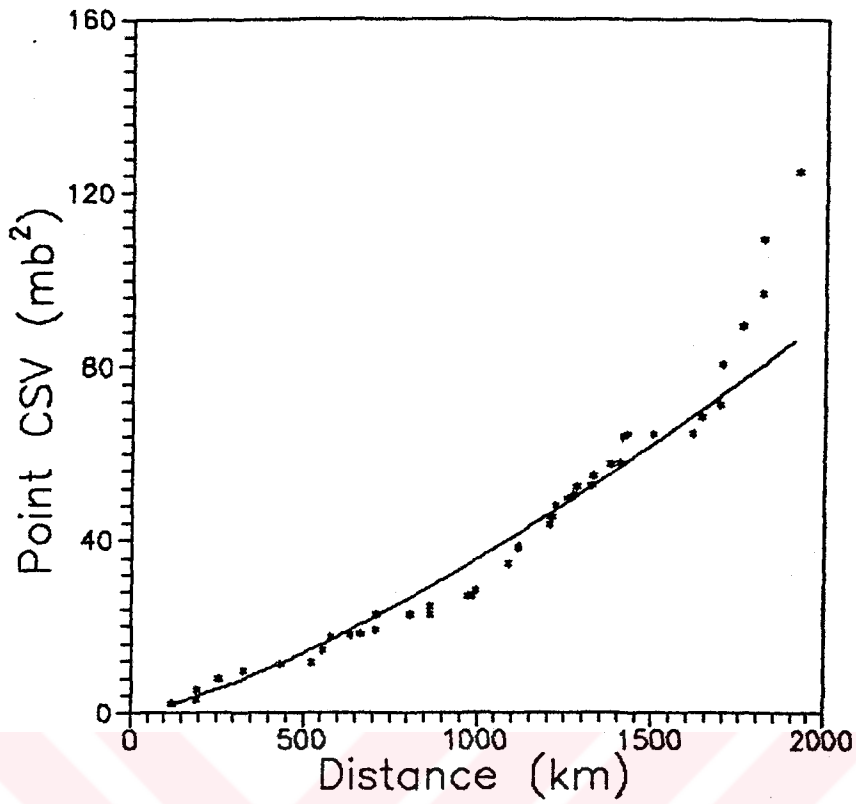


Figure A.5. Point CSV for station no. 11968.

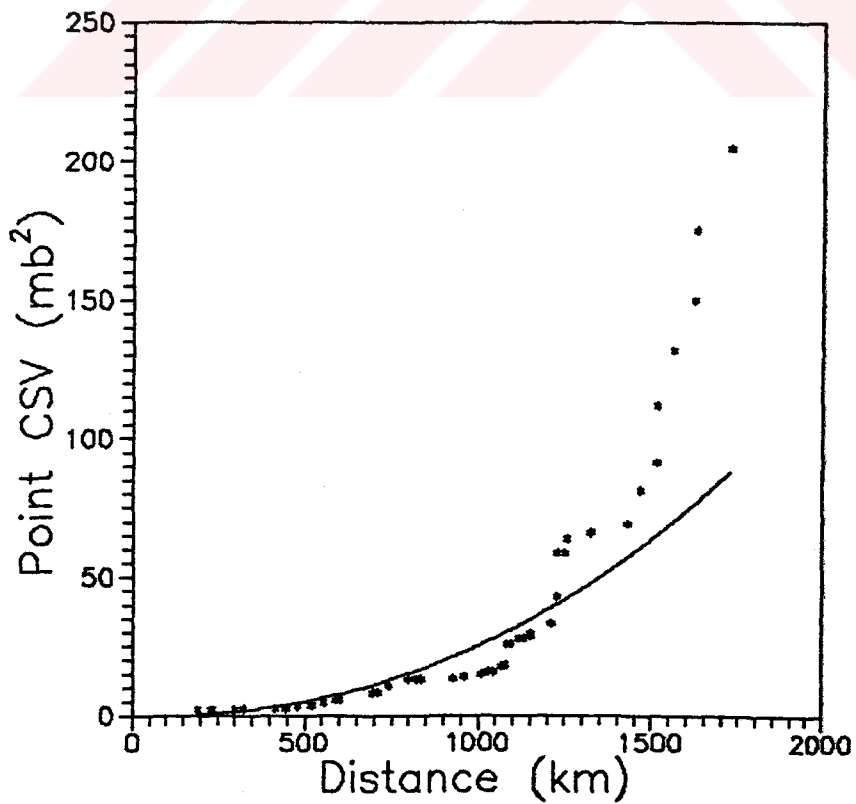


Figure A.6. Point CSV for station no. 15004.

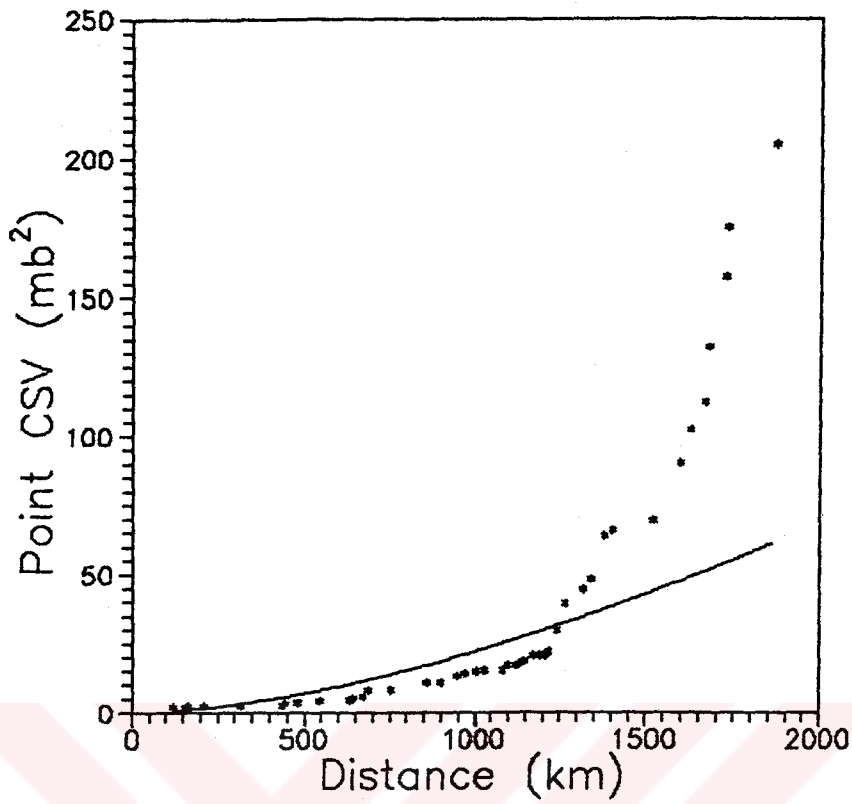


Figure A.7 Point CSV for station no. 12882.

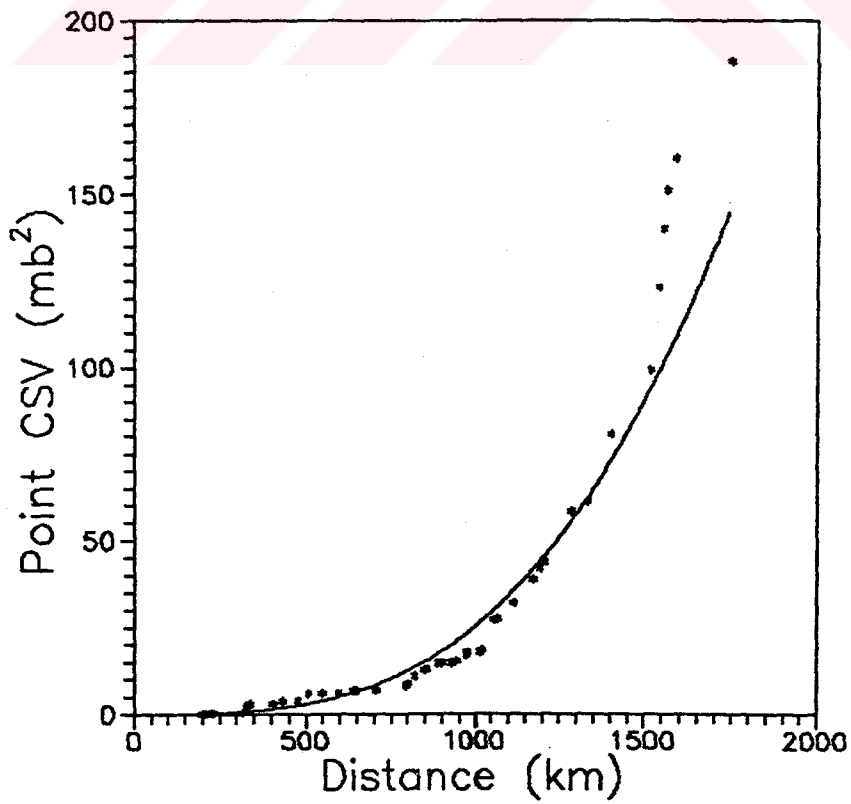


Figure A.8, Point CSV for station no. 15230.

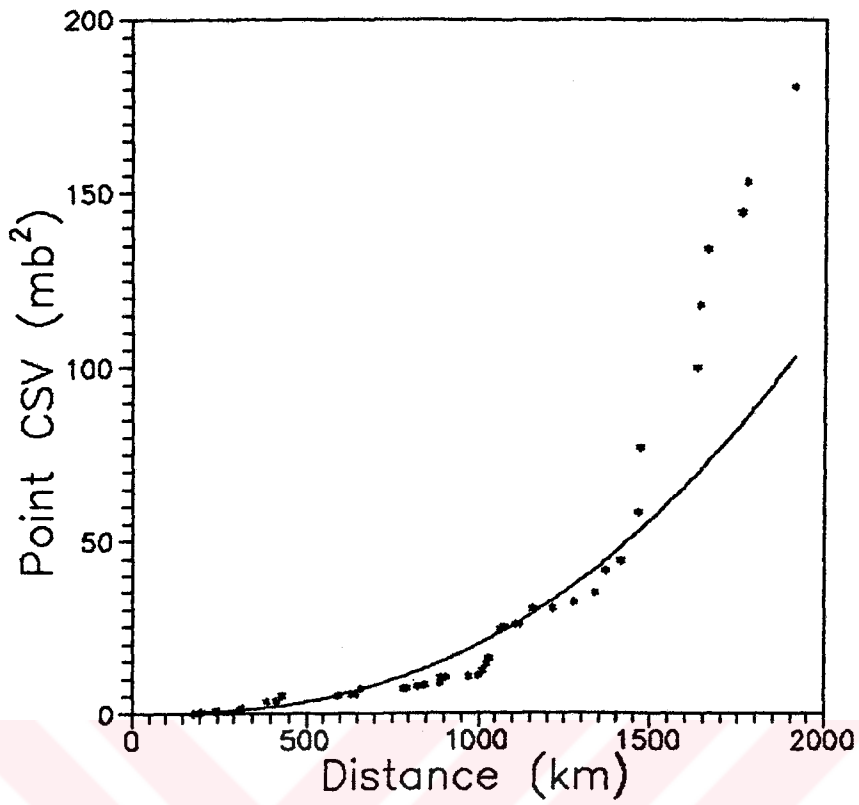


Figure A.9. Point CSV for station no. 13275.

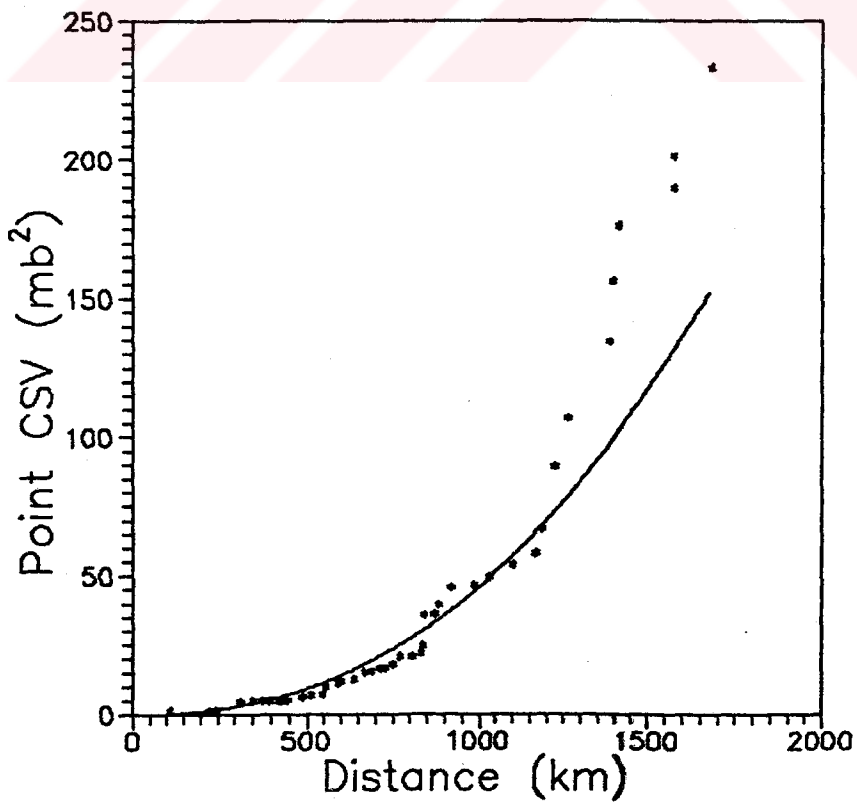


Figure A.10. Point CSV for station no. 15511.

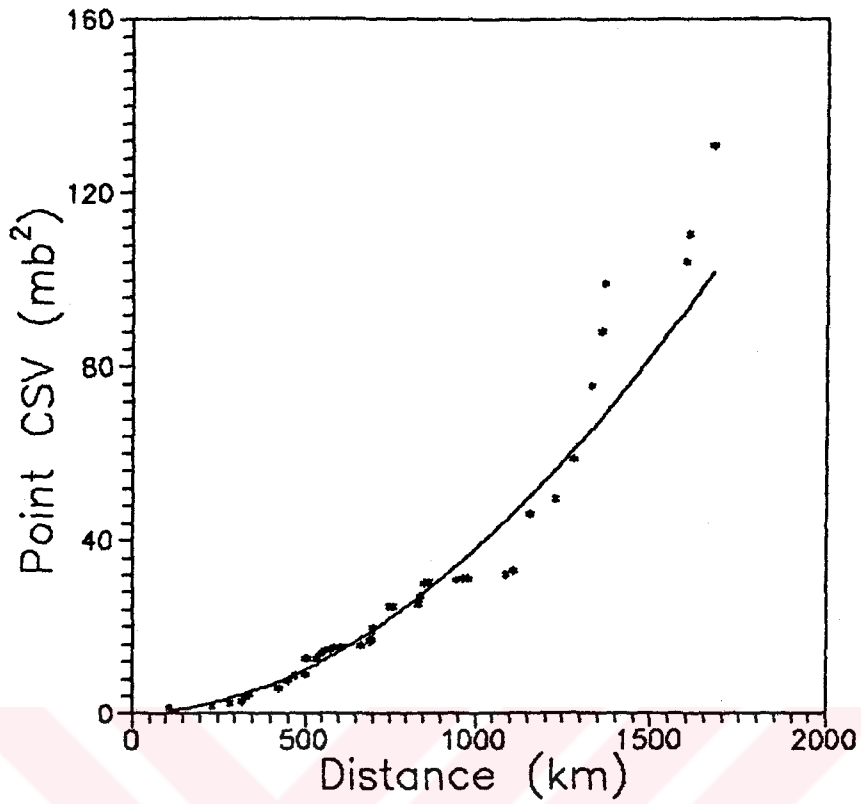


Figure A.11 Point CSV for station no. 15614.

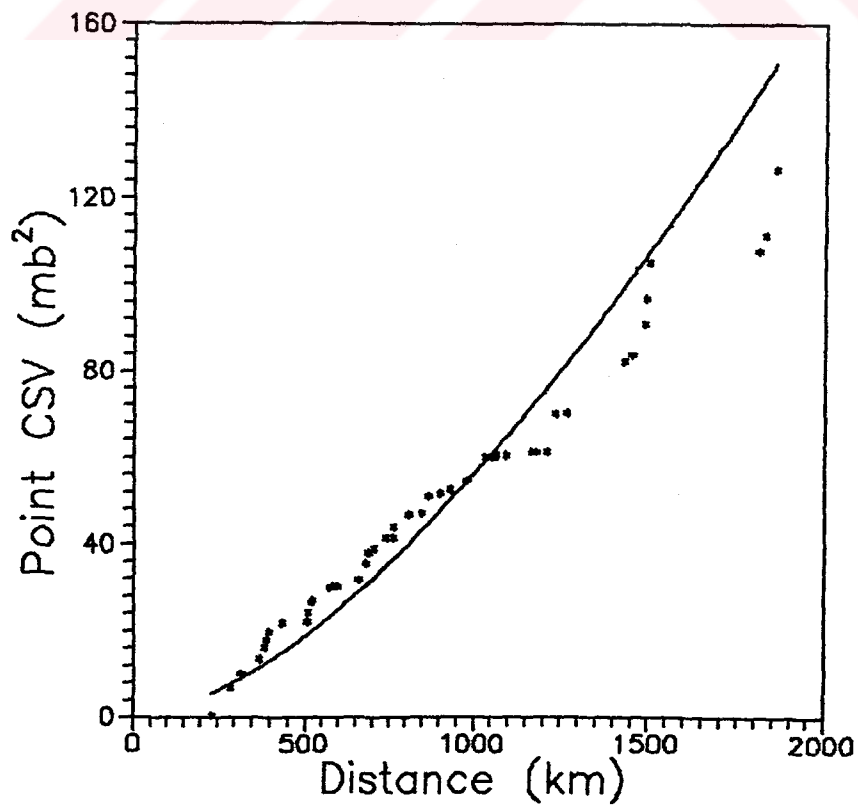


Figure A.12 Point CSV for station no. 13583.

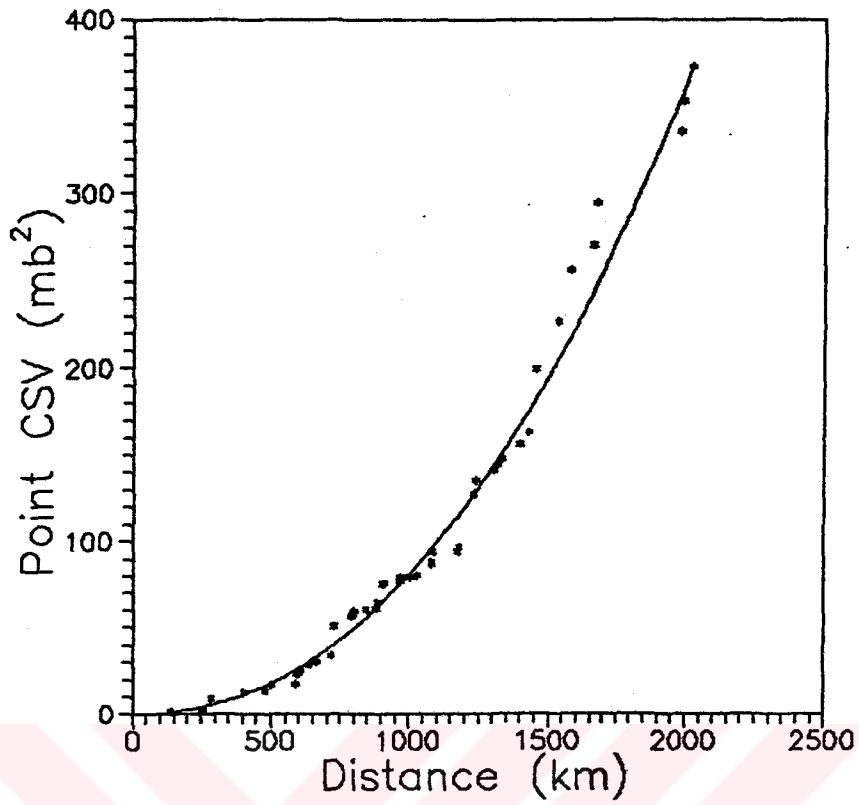


Figure A.13 Point CSV for station no. 16643.

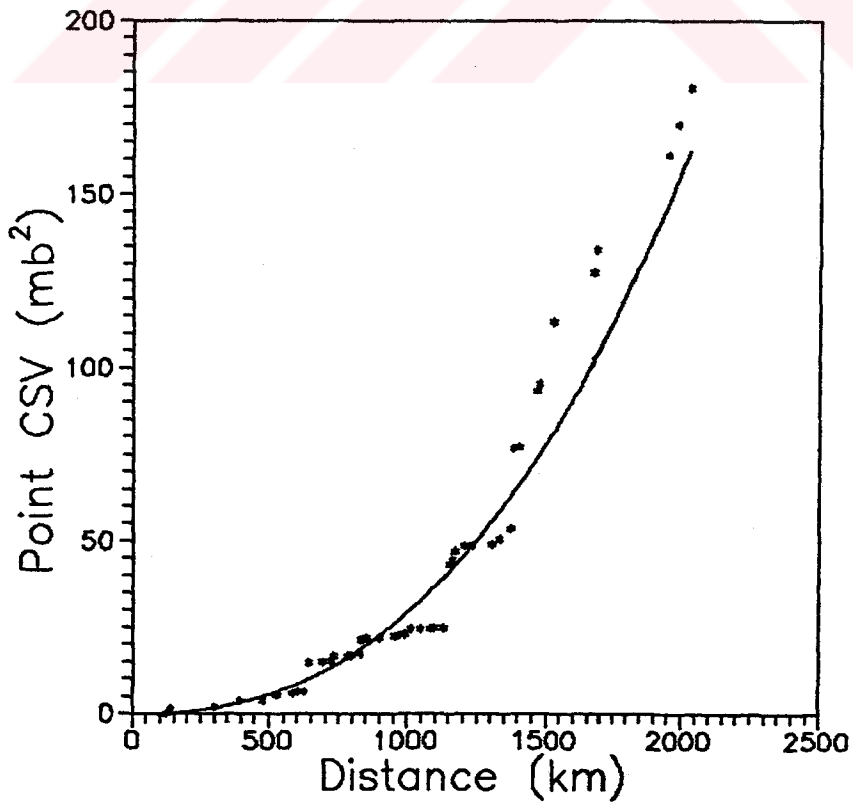


Figure A.14. Point CSV for station no. 16682.

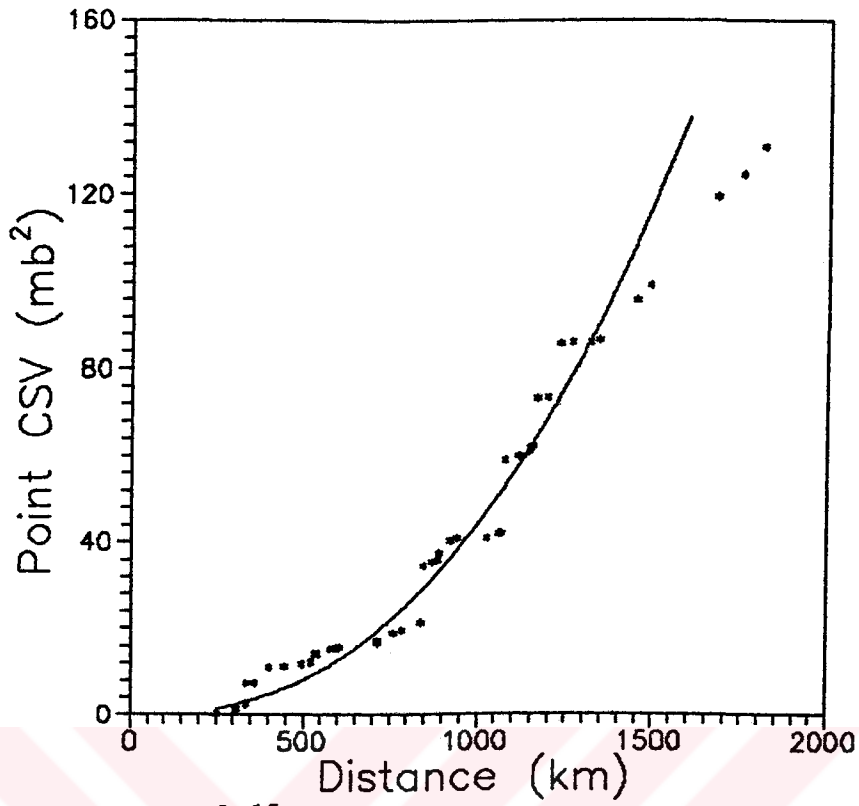


Figure A.15. Point CSV for station no. 16730.

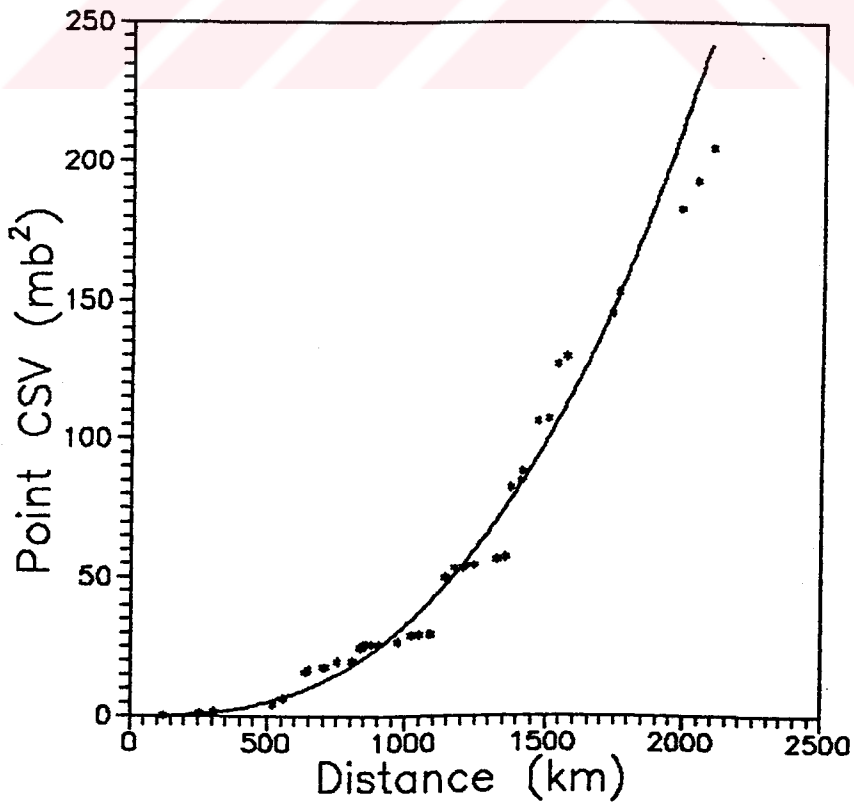


Figure A.16. Point CSV for station no. 16734.

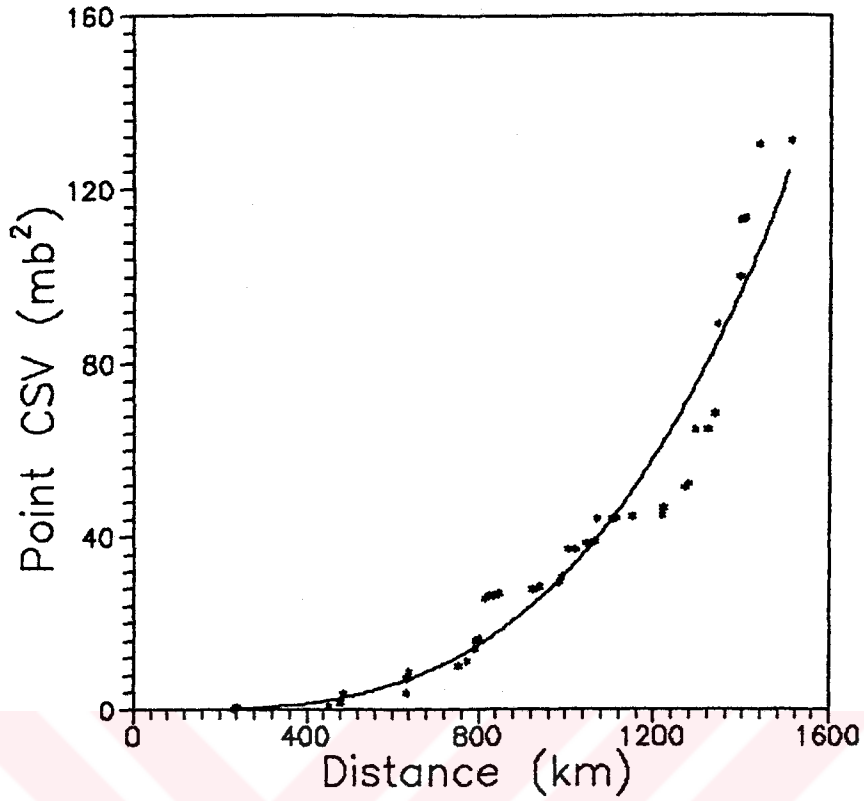


Figure A.17 Point CSV for station nb. 33587.

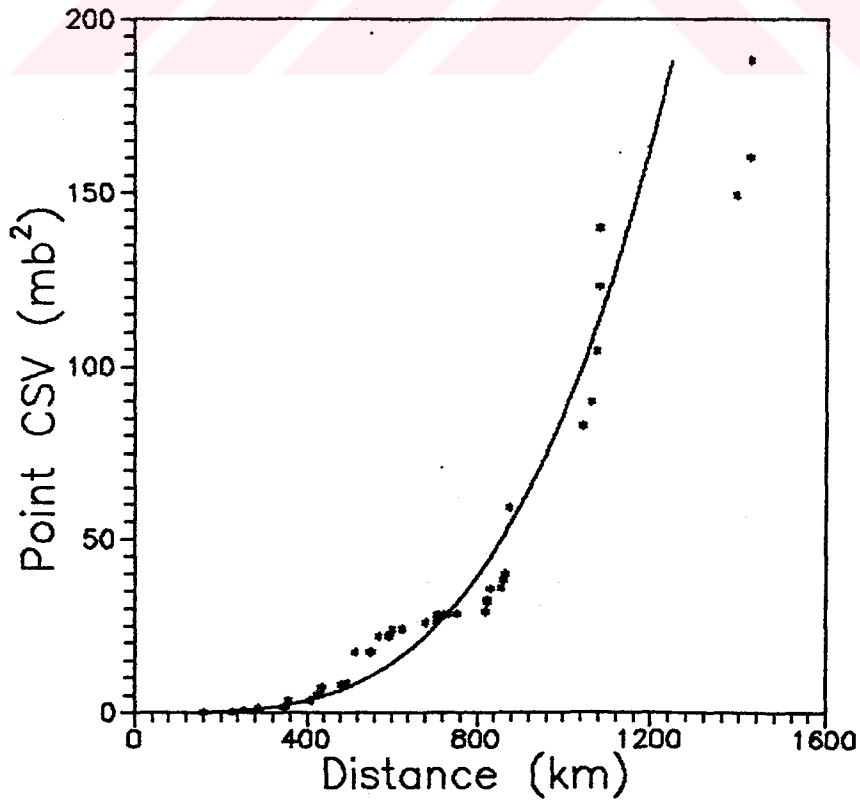


Figure A.18 Point CSV for station no. 17050.

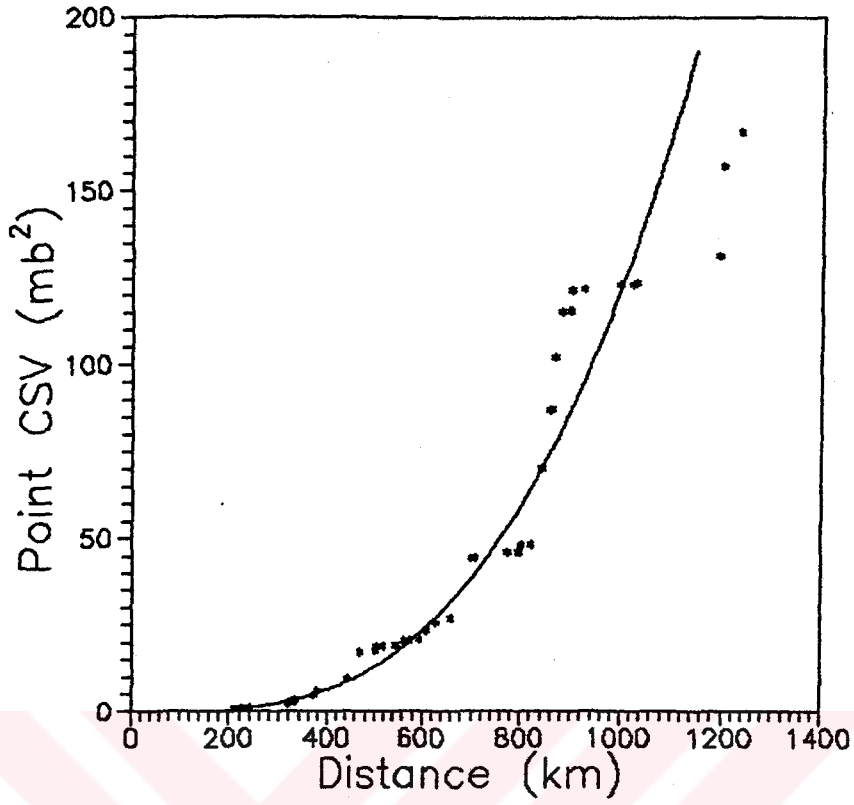


Figure A.19 Point CSV for station no. 17059.

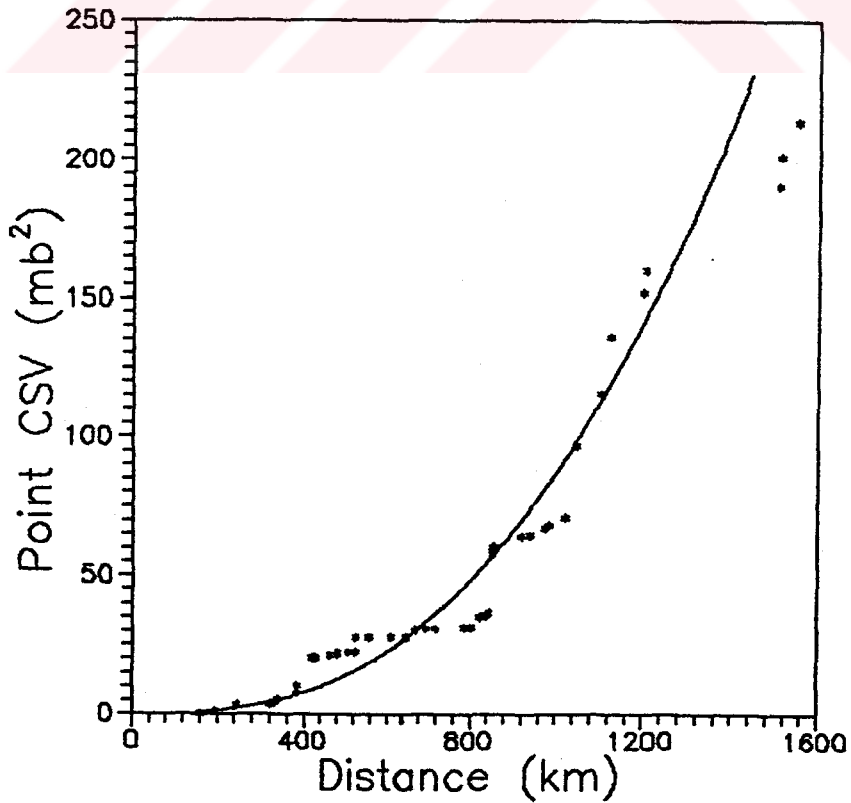


Figure A.20 Point CSV for station no. 17110.

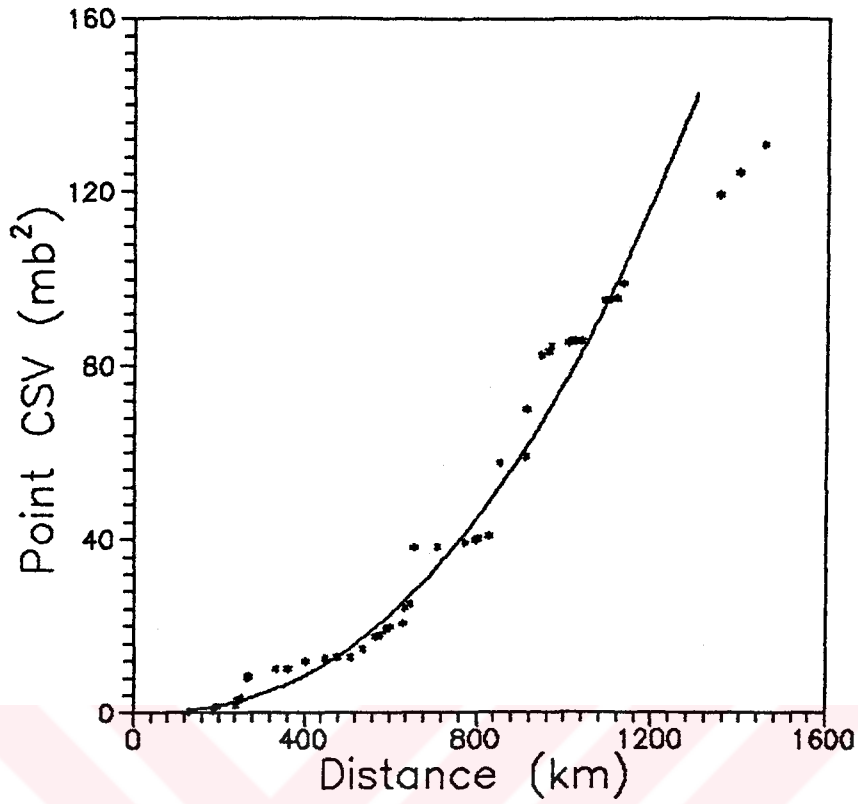


Figure A.21 Point CSV for station no. 17150.

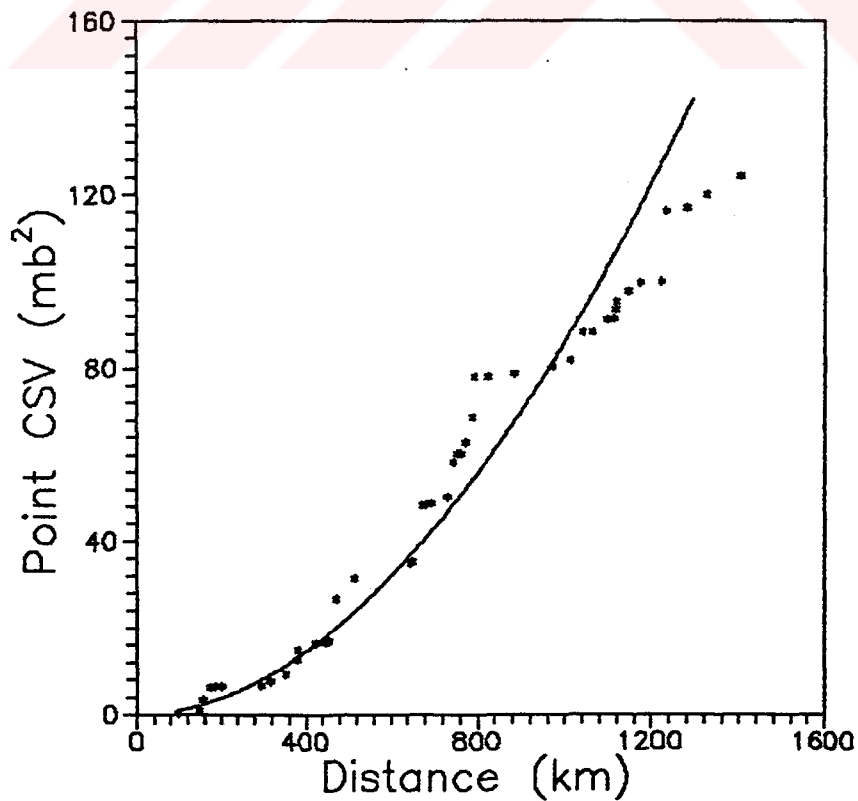


Figure A.22 Point CSV for station no. 17188.

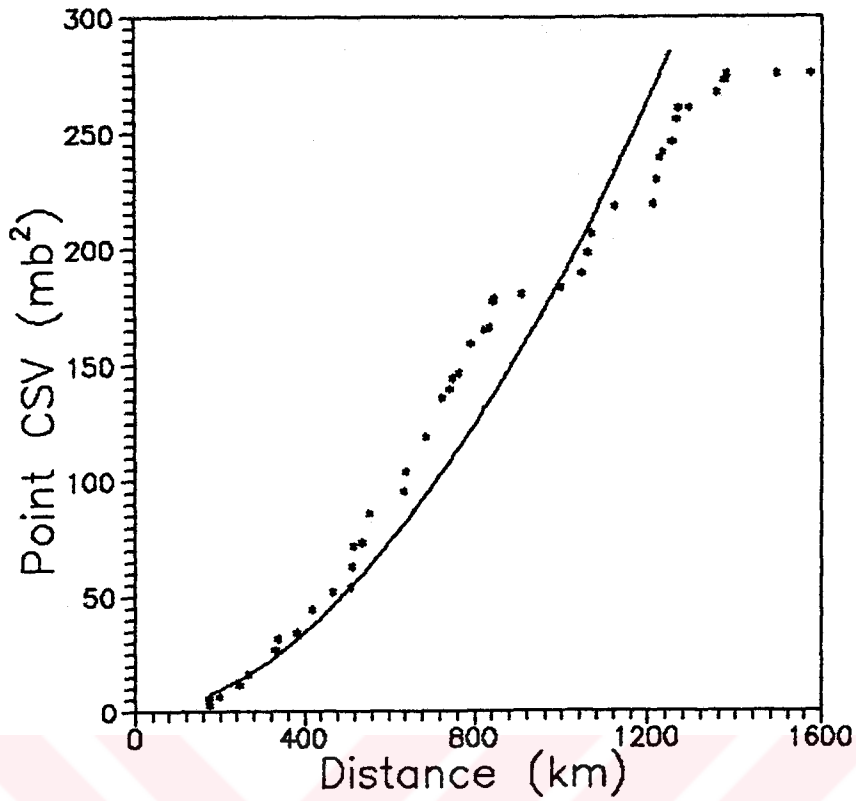


Figure A.23 Point CSV for station no. 17292.

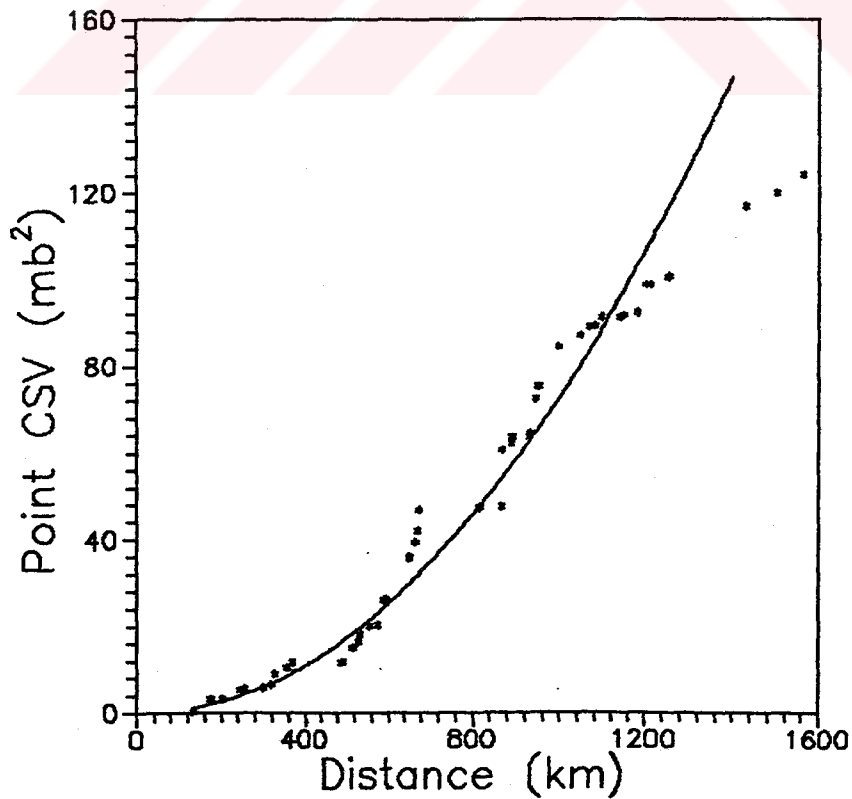


Figure A.24 Point CSV for station no. 17218.

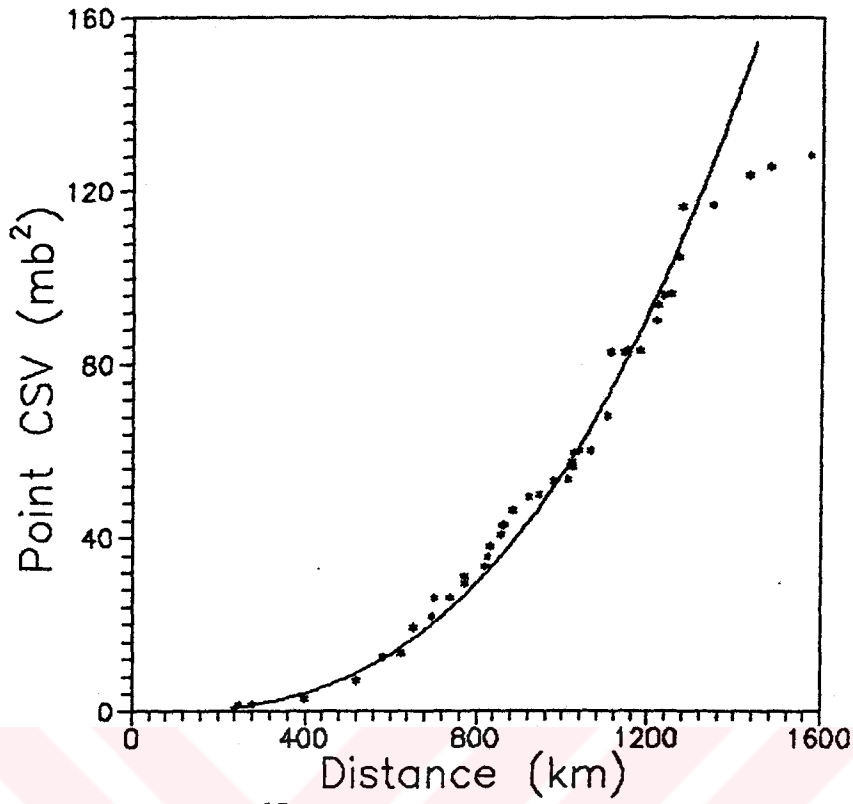


Figure A.25 Point CSV for station no. 33791.

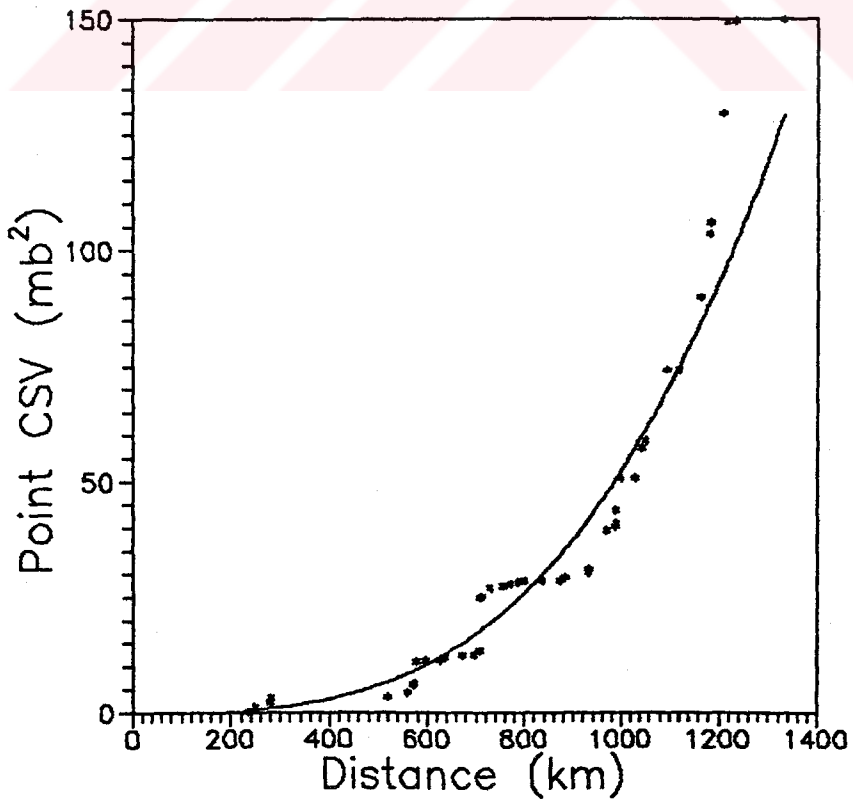


Figure A.26 Point CSV for station no. 33837.

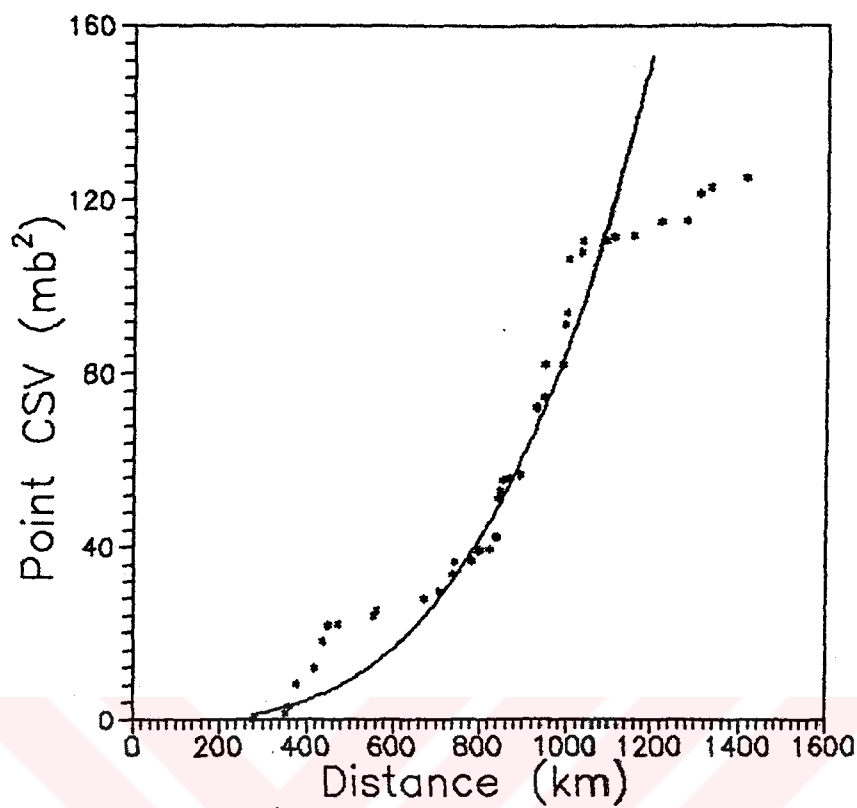


Figure A.27 Point CSV for station no. 33946.

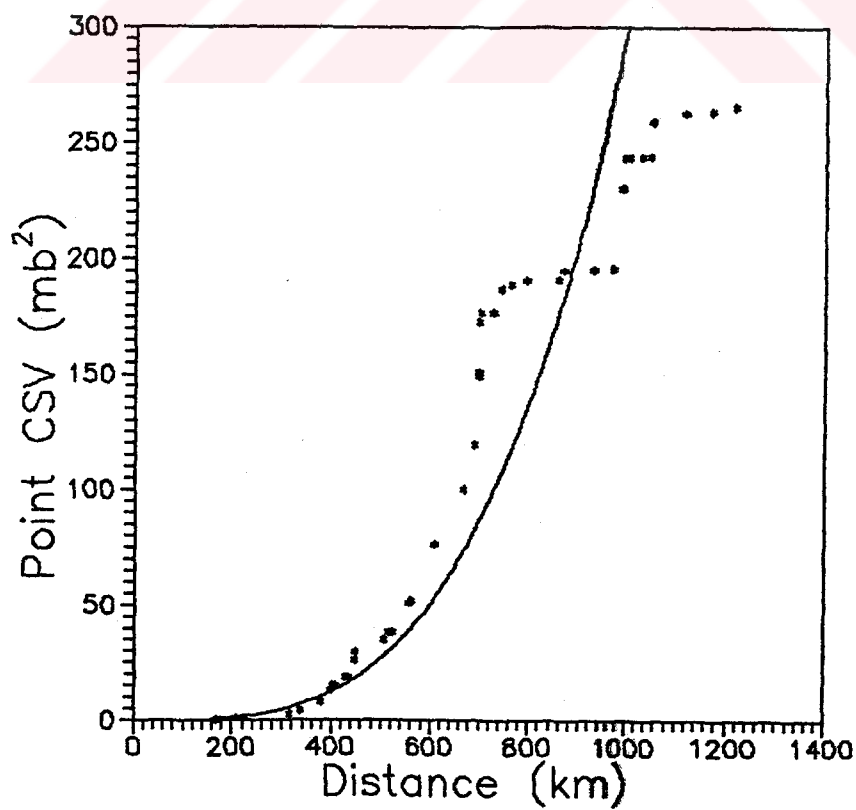


Figure A.28 Point CSV for station no. 17022.

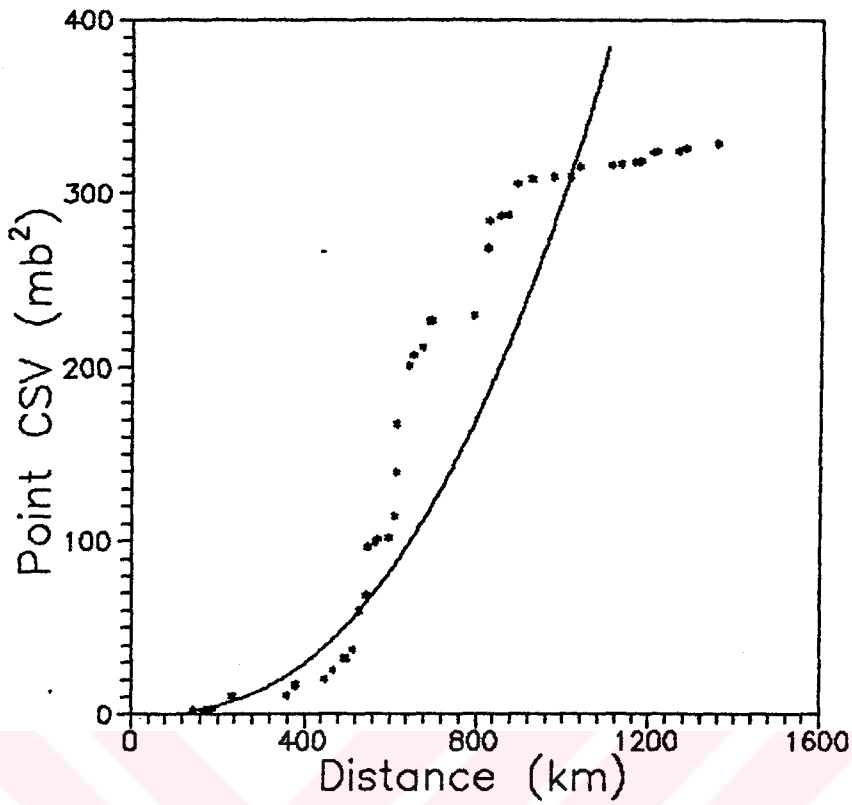


Figure A.29 Point CSV for station no. 17024.

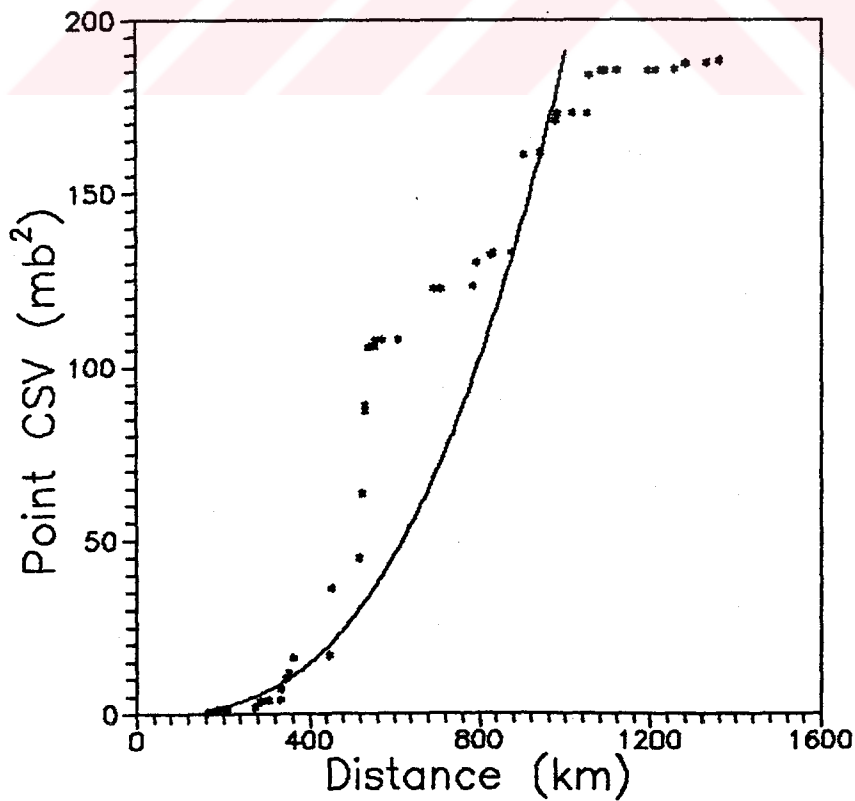


Figure A.30 Point CSV for station no. 17128.

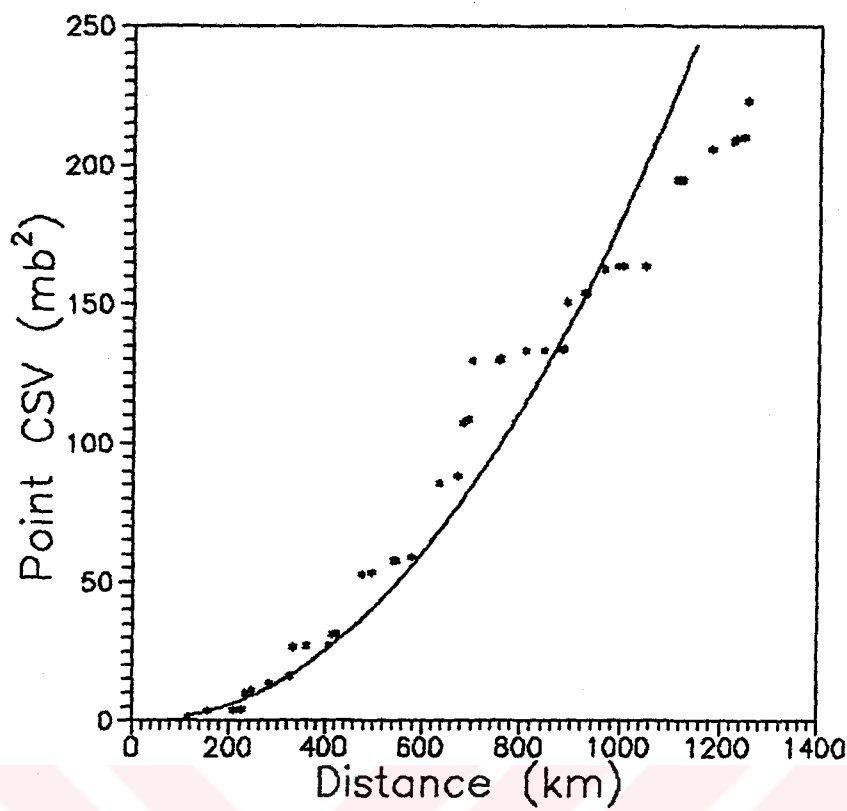


Figure A.31 Point CSV for station no. 17124.

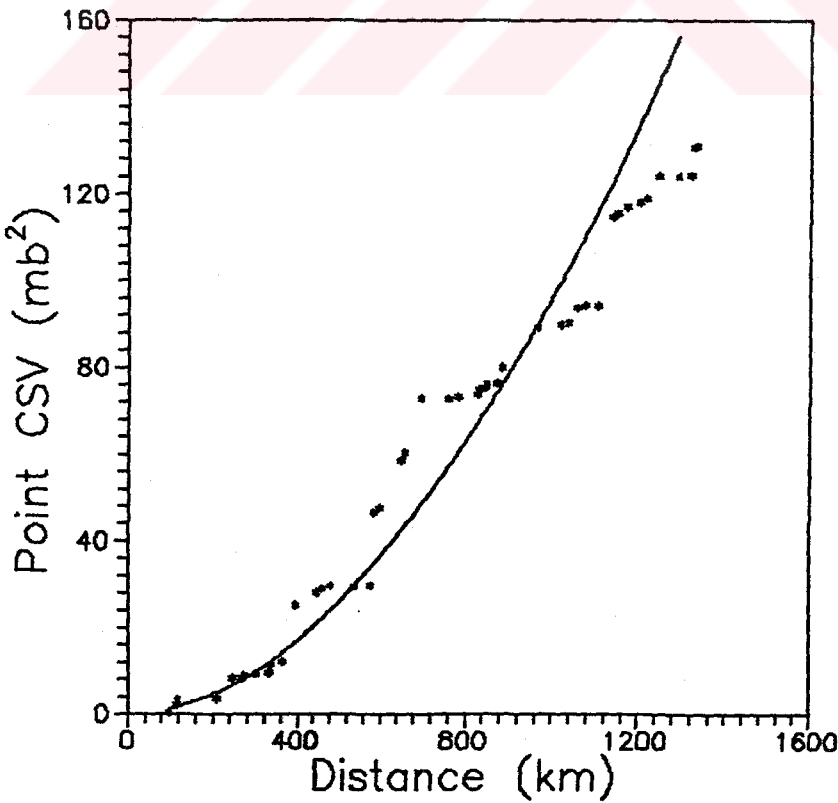


Figure A.32 Point CSV for station no. 17190.

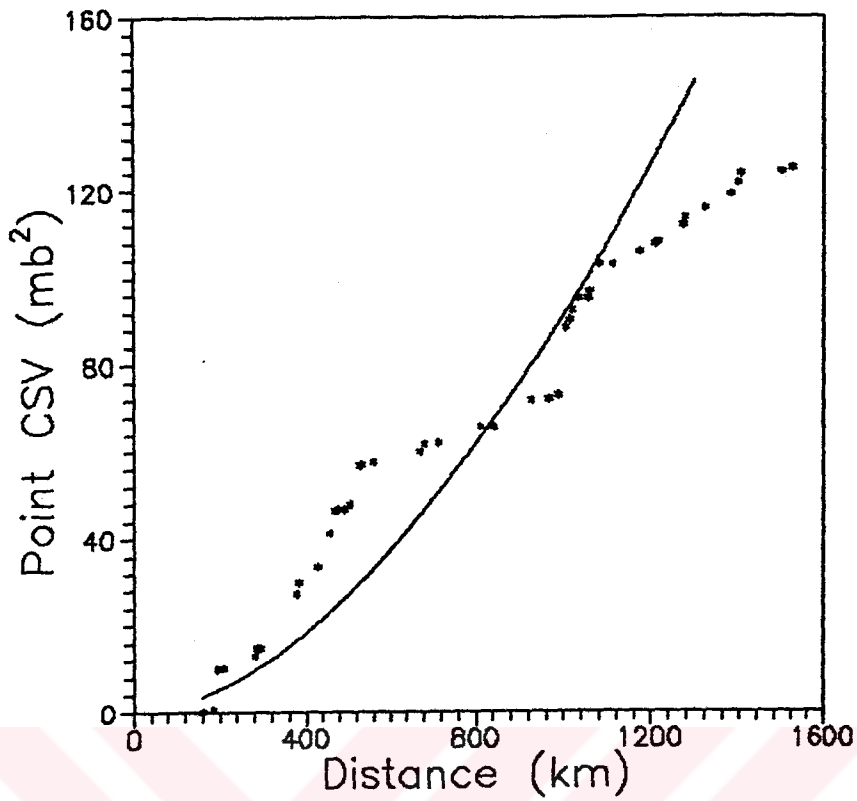


Figure A.33 Point CSV for station no. 17244.

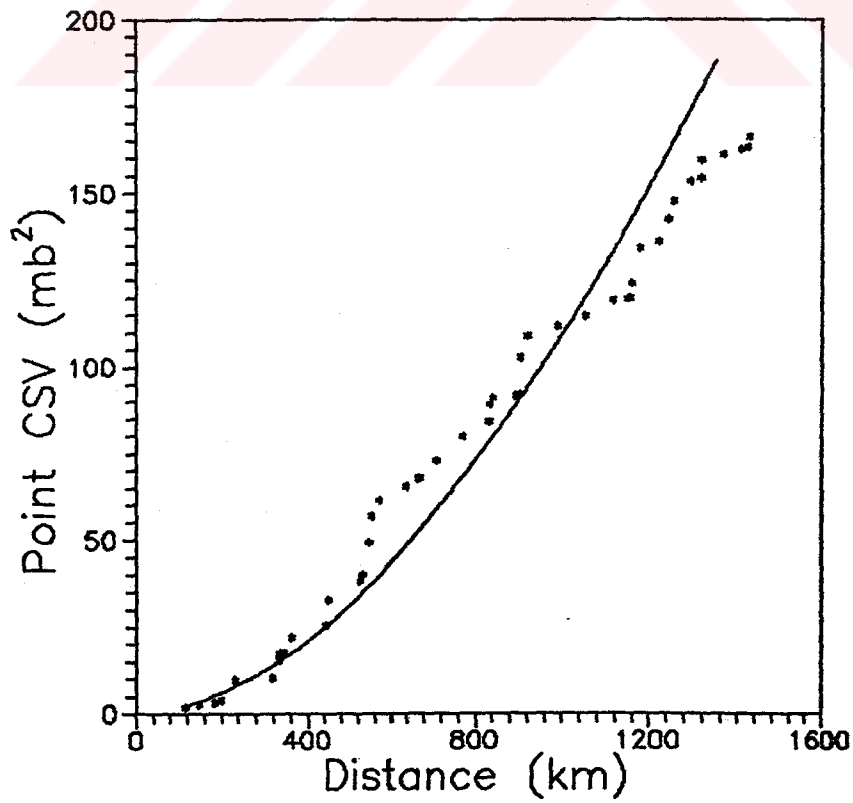


Figure A.34 Point CSV for station no. 17240.

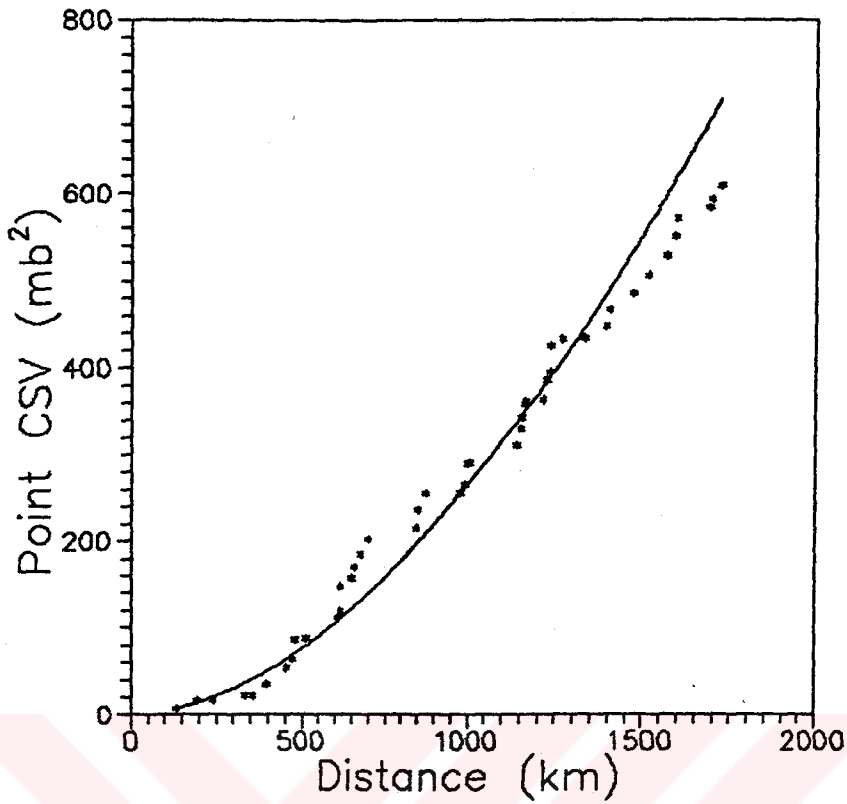


Figure A.35 Point CSV for station no. 17330.

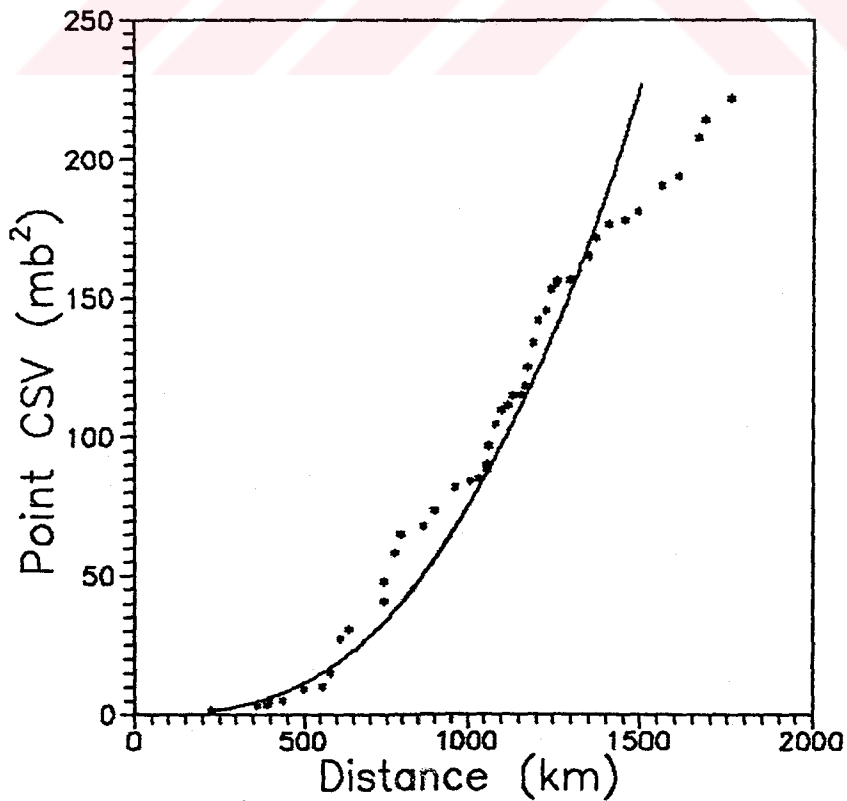


Figure A.36 Point CSV for station no. 34824.

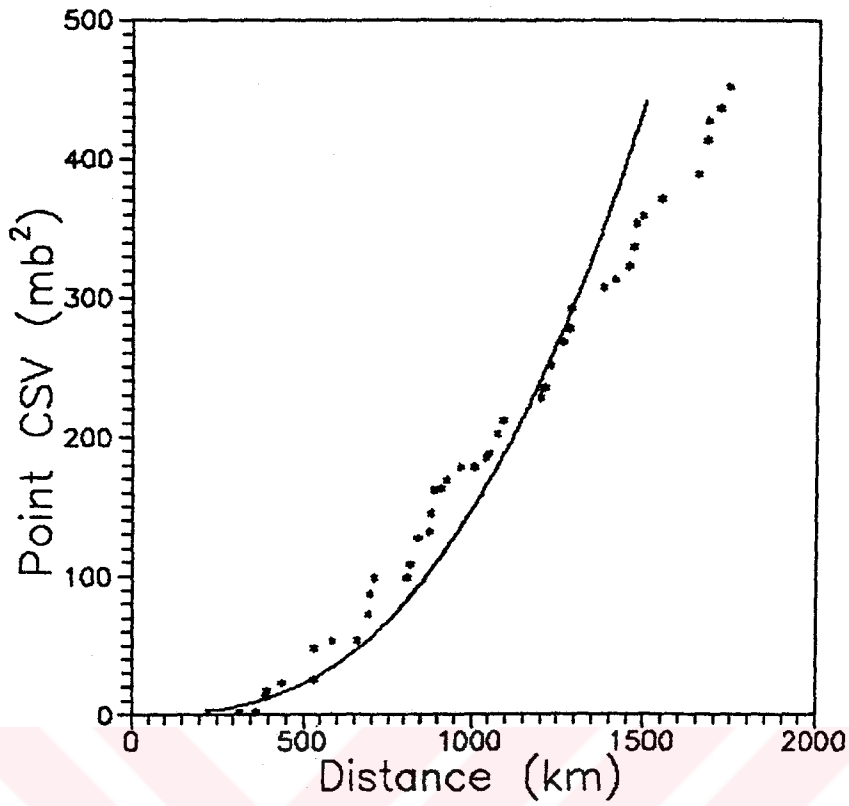


Figure A.37 Point CSV for station no. 37018.

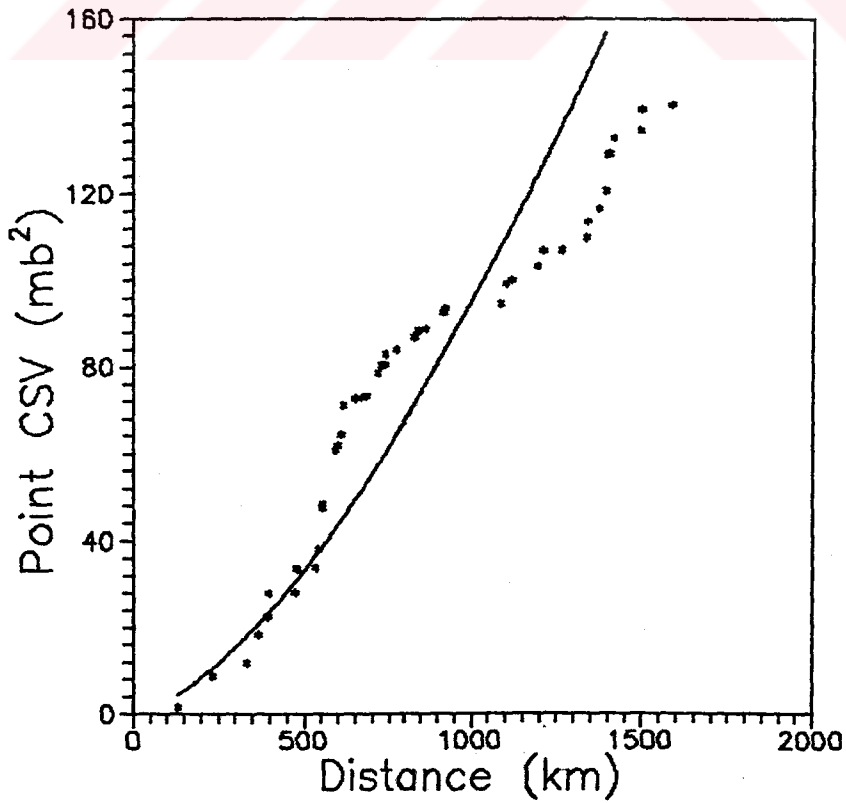


Figure A.38 Point CSV for station no 17030.

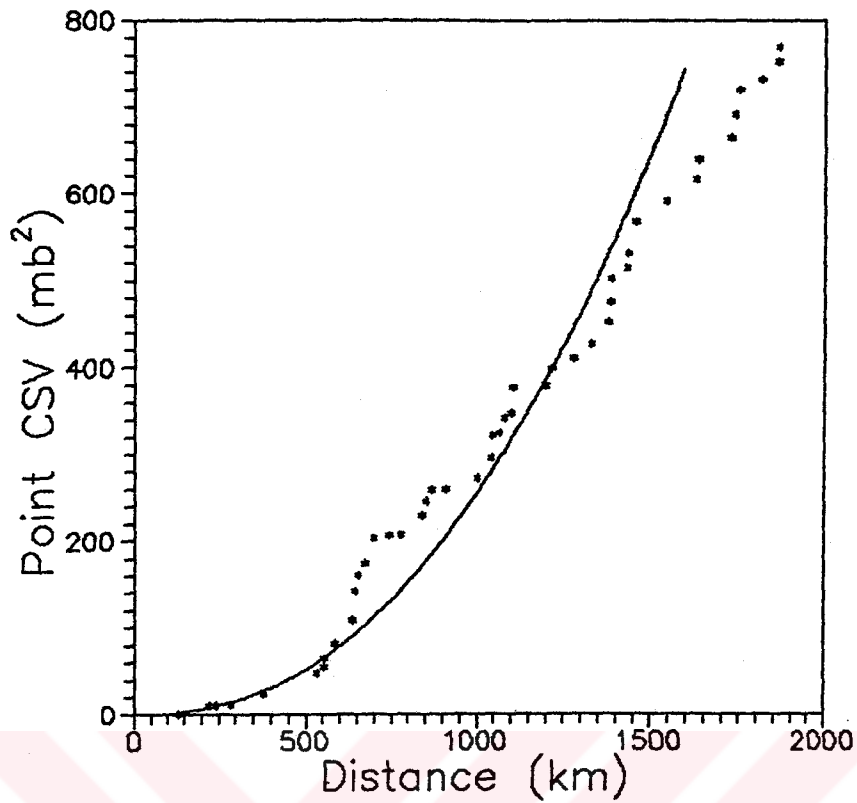


Figure A.39 Point CSV for station no. 17370.

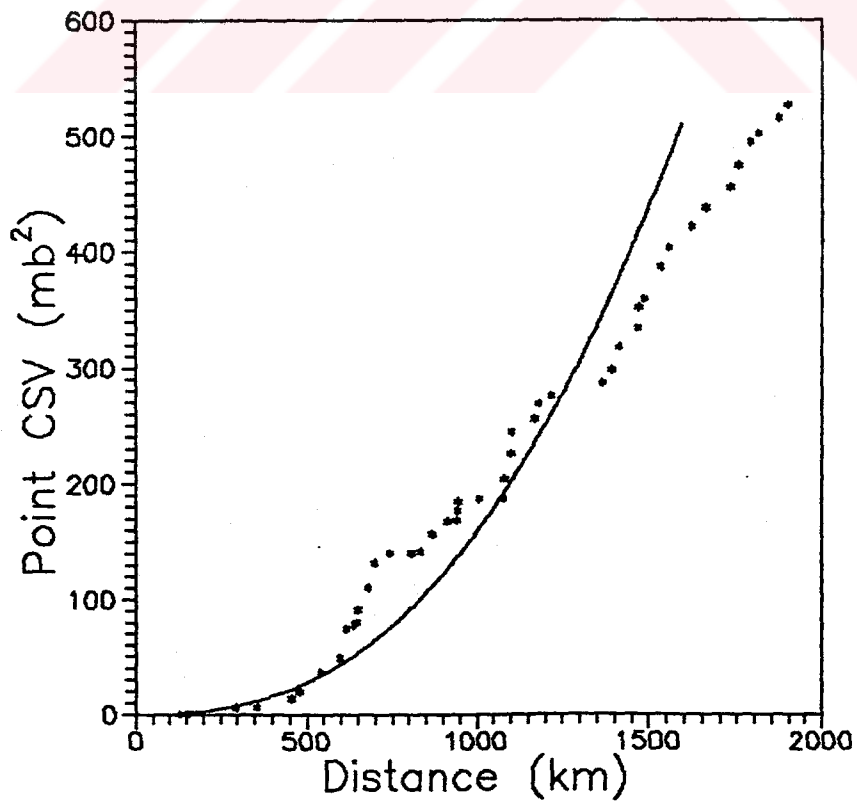


Figure A.40 Point CSV for station no. 17260.

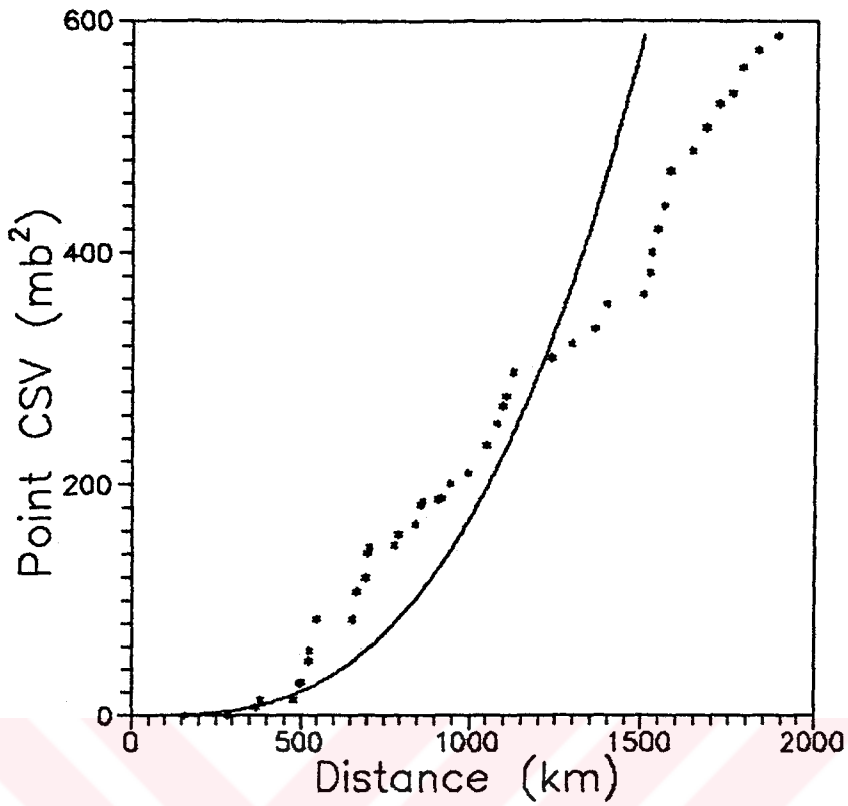


Figure A.41 Point CSV for station no. 17200.

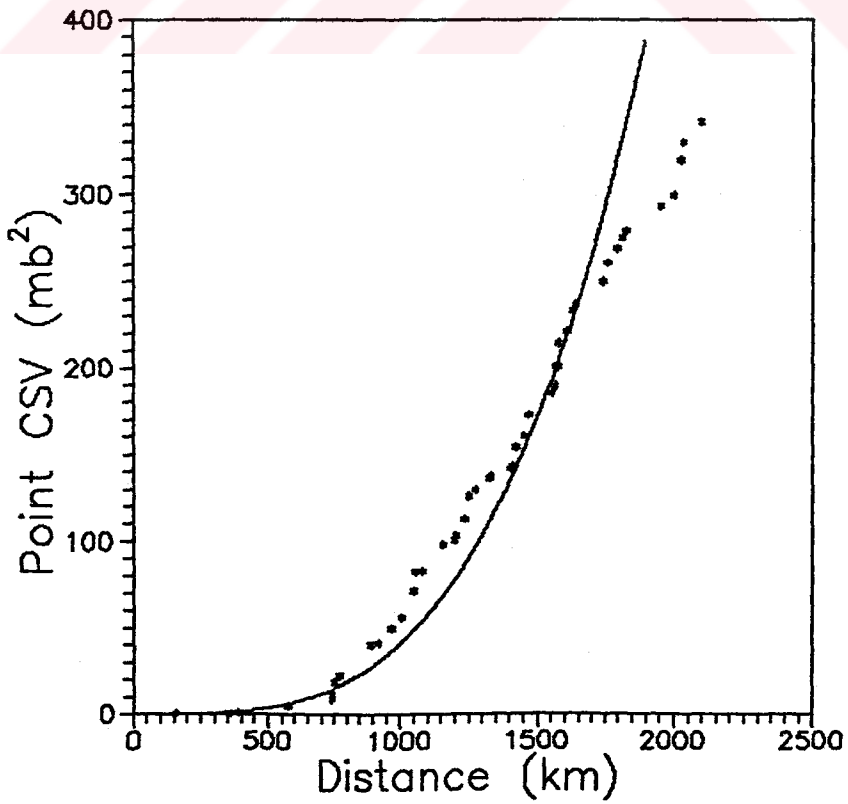


Figure A.42 Point CSV for station no. 34858.

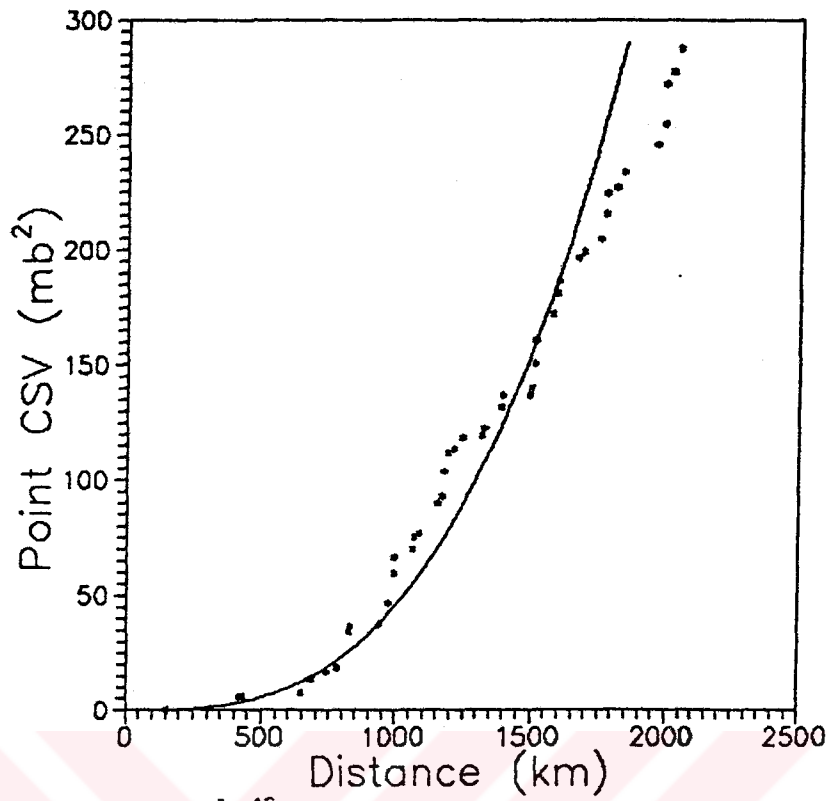


Figure A.43 Point CSV for station no. 37054.

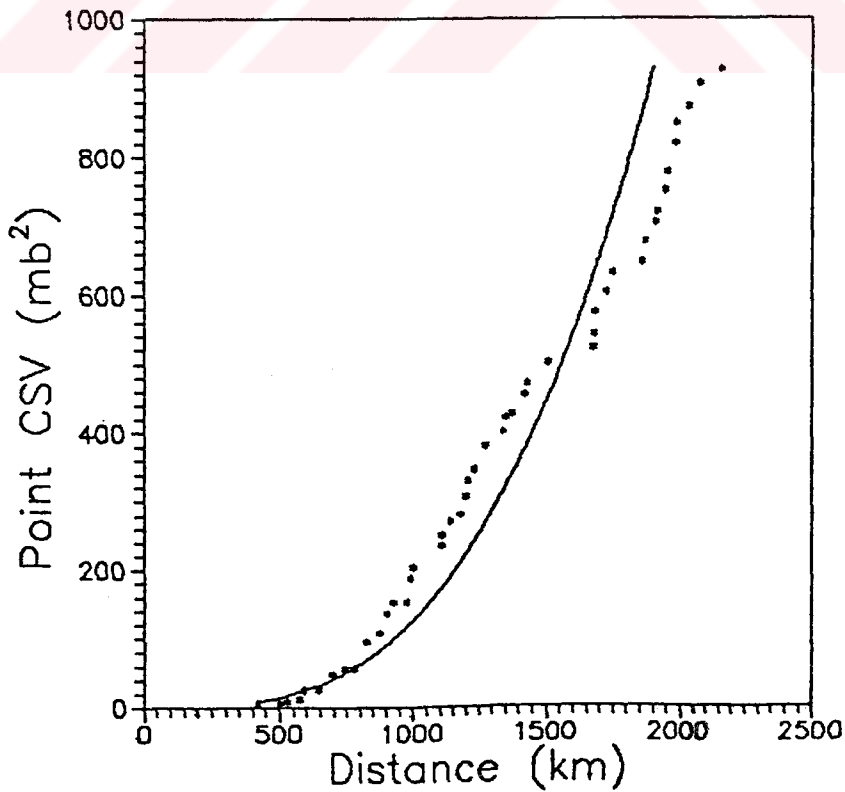


Figure A.44 Point CSV for station no. 17098.

APPENDIX B

(COMPUTER SOFTWARE)

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MAP PROJECTION

```

DECLARE SUB WRFILE (NS!, XS!(), YS!(), Z!())
DECLARE SUB RDFILE1 (NS!, STNO!(), LAT!(), LON!(), ZO!())
DECLARE SUB POLAR2 (NS!, DS!, IMAX!, JMAX!, LAT0!, LON0!, LAT!(),
LON!(), XS!(), YS!())

```

MAP PROJECTION

PURPOSES :

THIS PROGRAM CONSTRUCTS MAP PROJECTION BY USING POLAR
STEREOGRAPHIC PROJECTION

INPUT REQUIRED :

NS -----> NUMBER OF OBSERVING STATIONS.
STNO -----> LOCATION'S NUMBER OF STATIONS.
LAT -----> LATITUDE OF STATIONS.
LON -----> LONGITUDE OF STATIONS.
Z -----> ANY MET. PARAMETERS.

OUTPUT :

X -----> LOCATION OF STATIONS IN X-COORDINATE.
Y -----> LOCATION OF STATIONS IN Y-COORDINATE.
Z -----> ANY MET. PARAMETERS.

```

CLS
IMAX = 7: JMAX = 6: NS = 19: LAT0 = 43: LON0 = 30: dlon = 3
A = 6370: pi = 3.14159
DIM STNO(NS): DIM LAT(NS): DIM LON(NS): DIM Z(NS)
DIM XS(NS): DIM YS(NS)
DS = (2 * pi * A / 360) * dlon
CALL RDFILE1(NS, STNO(), LAT(), LON(), Z())
CALL POLAR2(NS, DS, IMAX, JMAX, LAT0, LON0, LAT(), LON(), XS(),
YS())
CALL WRFILE(NS, XS(), YS(), Z())
END

```

SUBROUTINE POLAR2

THIS SUBROUTINE IS CONVERTING A LATITUDE AND LONGITUDE OF
STATIONS TO THE ' X ' AND ' Y ' POSITIONS BY USING POLAR
STEREOGRAPHIC ,FOR LIMITED AREA AREA ANALYSIS DEFINE A MAP
ORIGIN AND STANDARD PARALLEL LATITUDE AT LATITUDE LAT0 AND
LONGITUDE LON0

```

SUB POLAR2 (NS, DS, IMAX, JMAX, LAT0, LON0, LAT(), LON(), XS(), YS())
A = 6370
G = 57.29578
FOR K = 1 TO NS
M = (1 + SIN(LAT0 / G)) / (1 + SIN(LAT(K) / G))

```

```

XB = A * M * COS (LAT(K) / G) * SIN((LON(K) - LON0) / G)
YE = A * (COS (LAT0 / G) - M * COS (LAT(K) / G) * COS((LON(K) - LON0) /
G))
XS(K) = XB + ((IMAX - 1) * DS) / 2
YS(K) = YE + ((JMAX - 1) * DS) / 2
NEXT
END SUB

```

```

-----
'
'
'               SUBROUTINE RDFILE
'
'   THIS SUBROUTINE READ A DATA FOR OBSERVATION STATIONS ,DATA
'   SHOULD BE ARRANGED IN EXTERNAL FILE ,LIKE SO :
'
'
'   STNO(1)          LAT(1)          LON(1)          ZO(1)
'   STNO(2)          LAT(2)          LON(2)          ZO(2)
'   ...             ...             ...             ...
'   ...             ...             ...             ...
'   ...             ...             ...             ...
'   STNO(NS)         LAT(NS)         LON(NS)         LON(NS)
'
'
'-----

```

```

SUB RDFILE (NS, STNO(), LAT(), LON(), ZO()) STATIC
PRINT "FILE NAME OF STATION DATA TO OPEN "
INPUT N1$
N2$ = ".DAT"
N$ = N1$ + N2$
OPEN "I", #1, N$
FOR I = 1 TO NS
IF EOF(1) THEN 10
INPUT #1, STNO(I), LAT(I), LON(I), ZO(I)
NEXT I
10 CLOSE
END SUB

```

```

-----
'
'
'               SUBROUTINE WRFILE
'
'   THIS SUBROUTINE WRITE A DATA FOR STATION ,DATA SHOULD BE
'   ARRANGED IN EXTERNAL FILE , LIKE SO :
'
'   X(1)    Y(1)    Z(1)
'   X(2)    Y(2)    Z(1)
'   ....    ...    ....
'   ....    ...    ....
'
'
'   ...    ...    ....
'   X(NS)  Y(NS)  Z(NS)
'
'-----

```

```

SUB WRFILE (NS, XS(), YS(), Z()) STATIC
PRINT "FILE NAME OF RESULT TO CREAT "
INPUT k1$
k2$ = ".dat"
K$ = k1$ + k2$

```

```
OPEN "O", #1, KS  
FOR I = 1 TO NS  
PRINT #1, XS(I), YS(I), Z(I)  
PRINT XS(I), YS(I), Z(I)  
NEXT I  
CLOSE #1  
END SUB
```



CSV

```

DECLARE SUB CUMUL (M!, ZSD!(), CSV!())
DECLARE SUB SEMIVAR (M!, k!, R!(), ZSD!(), SV!(), D!())
DECLARE SUB WRFILE (NO!, VAR1!(), VAR2!(), NAMES)
DECLARE SUB SORT (M!, R!(), ZSD!())
DECLARE SUB DISTANCE (NS!, X!(), Y!(), R!())
DECLARE SUB ZSQD (NS!, Z!(), ZSD!())
DECLARE SUB RDFILE1 (NS!, X!(), Y!(), Z!())
'-----
'
'                                CSV
'
'   THIS PROGRAM TO CALCULATE THE CUMULATIVE SEMIVARIOGRAM FOR
'   REPRESENTING REGIONAL VARIABILITY
'
'-----
CLS
NS = 47
M = NS * (NS - 1) / 2
DIM X(NS): DIM Y(NS): DIM Z(NS): DIM R(NS * NS): DIM ZSD(NS * NS)
DIM CSV(M)
CALL RDFILE1(NS, X(), Y(), Z())
CALL DISTANCE(NS, X(), Y(), R())
CALL ZSQD(NS, Z(), ZSD())
CALL SORT(M, R(), ZSD())
CALL CUMUL(M, ZSD(), CSV())
CALL WRFILE(M, R(), CSV(), "CSV.DAT")
END
'-----

SUB CUMUL (M, ZSD(), CSV())
SUM = 0
FOR i = 1 TO M
CSV(i) = ZSD(i) + SUM
SUM = CSV(i)
NEXT i
END SUB
'-----

SUB DIS (NS, X(), Y(), R())
k = 0
FOR i = 1 TO NS
FOR j = 1 TO NS
IF i = j THEN EXIT FOR
k = k + 1
R(k) = INT(SQR((X(i) - X(j)) ^ 2 + (Y(i) - Y(j)) ^ 2))
NEXT j
NEXT i
END SUB
'-----

SUB RDFILE1 (NS, X(), Y(), Z()) STATIC
OPEN "I", #1, "px.DAT"
FOR i = 1 TO NS
IF EOF(1) THEN 10
INPUT #1, X(i), Y(i), Z(i)
PRINT i
NEXT i

```

```
10 CLOSE
END SUB
'
```

```
SUB SORT (M, R(), ZSD())
FOR j = 1 TO M - 1
FOR i = j + 1 TO M
IF R(j) <= R(i) THEN GOTO 20
k = R(j): R(j) = R(i): R(i) = k
l = ZSD(j): ZSD(j) = ZSD(i): ZSD(i) = l
20 NEXT i
PRINT j
NEXT j
END SUB
'
```

```
SUB WRFILE (NO, VAR1(), VAR2(), NAMES) STATIC
OPEN "O", #1, NAMES
FOR i = 1 TO NO
PRINT #1, VAR1(i), VAR2(i)
NEXT i
CLOSE #1
END SUB
'
```

```
SUB ZSQD (NS, Z(), ZSD())
SUM = 0
FOR i = 1 TO NS
FOR j = 1 TO NS
IF i = j THEN EXIT FOR
SUM = SUM + 1
ZSD(SUM) = INT((Z(i) - Z(j)) ^ 2) / 2
NEXT j
NEXT i
END SUB
```

POINT CSV MODEL

```

DECLARE SUB WRFILE (N!, X!(), Y!(), K$)
DECLARE SUB WRFILE1 (N!, X!(), Y!(), ZZ!(), K$)
DECLARE SUB RDFILE1 (ns!, XS!(), YS!(), Z!())
DECLARE SUB DIS (I!, ns!, X!(), Y!(), D!())
DECLARE SUB ZSQD (I!, ns!, Z!(), zsd!())
DECLARE SUB SORT (M!, R!(), zsd!())
DECLARE SUB CUMUL (M!, zsd!(), CSV!())
DECLARE SUB LSQM (N!, M!, X!(), F!(), C!())
DECLARE SUB GAUS1 (N!, M!, ND!, A!(), DELT!)
'-----
'
'                                POINT CSV MODEL
'
'                                " POWER MODEL "
'
'  THIS PROGRAM. TO MODELLING A DATA BY USING POWER MODEL
'  FOR CALCULATE THE INFLUENCING RADIUS AT STATIONS.
'
'  INPUT :
'
'      Z      ---> THE ARRAY OF ANY METEOROLOGICAL QUANTITY
'      X      ---> ARRAY OF LOCATION COORDINATE IN X-AXIS
'      Y      ---> ARRAY OF LOCATION COORDINATE IN Y-AXIS
'
'  OUTPUT :
'
'      RS      ---> ARRAY OF INFLUENCING RADIUS AT EVERY STATION
'-----
CLS
DEGREE = 1
IMAX = 9
JMAX = 7
ns = 47
DIM STNO(ns): DIM LAT(ns): DIM LON(ns): DIM Z(ns): DIM C(2)
DIM XG(IMAX, JMAX): DIM YG(IMAX, JMAX): DIM XS(ns): DIM
YS(ns)
DIM E(ns): DIM D(ns): DIM zsd(ns): DIM CSV(ns): DIM D1(ns):
DIM CSV1(ns)
DIM RS(ns): DIM RG(IMAX, JMAX)
DS = (2 * pi * A / 360) * dlon
CALL RDFILE1(ns, XS(), YS(), Z())
FOR ST = 1 TO ns
CALL DIS(ST, ns, XS(), YS(), D())
CALL ZSQD(ST, ns, Z(), zsd())
CALL SORT(ns - 1, D(), zsd())
CALL CUMUL(ns - 1, zsd(), CSV())
STA$ = STR$(ST)
NAME$ = "CS" + STA$ + ".DAT"
CALL WRFILE(ns - 1, D(), CSV(), NAME$)
L = 0
FOR I = 1 TO ns - 1
IF CSV(I) = 0 THEN 22
L = L + 1
D1(L) = LOG(D(I)): CSV1(L) = LOG(CSV(I))
22  NEXT I
CALL LSQM(L, DEGREE, D1(), CSV1(), C())

```

```

      ALFA = EXP(C(1))
      BETA = C(2)
      GAMMAX = EXP(CSV1(L))
      RS(ST) = (GAMMAX / (2 * ALFA)) ^ (1 / BETA)
      PRINT ST, RS(ST)
      NEXT ST
CALL WRFILE1(ns, XS(), YS(), RS(), "RST.DAT")
      END

```

```

-----
'
'               SUBROUTINE CUMUL
'
'   CALCULATE THE CUMULATIVE SUMS OF " HZSD "
'-----
SUB CUMUL (M, zsd(), CSV())
SUM = 0
FOR I = 1 TO M
CSV(I) = zsd(I) + SUM
SUM = CSV(I)
NEXT I
END SUB

```

```

-----
'
'               SUBROUTINE DIS
'
'   CALCULATE THE DISTANCE BETWEEN ONE STATION AND ALL OTHER
'   STATIONS.
'-----
SUB DIS (I, ns, X(), Y(), D())
K = 0
FOR J = 1 TO ns
IF I = J THEN 1000
K = K + 1
D(K) = SQR((X(I) - X(J)) ^ 2 + (Y(I) - Y(J)) ^ 2)
1000 NEXT J
END SUB

```

```

-----
'
'               SUBROUTINE GAUS1
'
'   FUNCTION :
'               THIS SUBROUTINE COMPUTE THE SOLUTION FOR M SYSTEM
'               WITH N EQUATION AND N UNKNOWNNS USING GAUSSIAN
'               ELIMINATION.
'
'   INPUT :
'               N ---> NUMBER OF EQUATION AND UNKNOWNNS
'               M ---> NUMBER OF SYSTEM ( RIGHT HAND SIDE VECTORS )
'               A ---> N BY M+N (USUALLY,M=1) ARRAY OF COEFFICIENTS
'                   AUGMENTED WITH EACH RIGHT SIDE VECTOR
'               DELT ---> ESTIMATE OF ERROR BOUND ( MACHINE EPSILON )
'
'   OUTPUT :
'               A(1,N+J),.....A(N,N+J)
'               = SOLUTION OF THE J-TH SYSTEM (J=1,.....,M)
'
'   REFERENCES:
'               SIDNEY YAKOWITZ, FERENC SZIDAROVSKY,"AN INTRODUCTION
'               TO NUMERICAL COMPUTATIONS ",SECOND EDITION,1990,
'-----

```

```

SUB GAUS1 (N, M, ND, A(), DELT)
'DIM A(ND, ND + M)
IF N > 1 THEN

```

```

FOR K = 1 TO (N - 1)
  PIV = ABS(A(K, K))
  KK = K + 1
  IN = K
  FOR I = KK TO N
    IF ABS(A(I, K)) > PIV THEN
      PIV = ABS(A(I, K))
      IN = I
    END IF
  NEXT I
  IF K <> IN THEN
    FOR J = K TO (M + N)
      X = A(K, J)
      A(K, J) = A(IN, J)
      A(IN, J) = X
    NEXT J
  END IF
  IF PIV < DELT THEN
    PRINT "THE MATRIX IS SINGULAR"
    EXIT SUB
  END IF
  FOR I = KK TO N
    FOR J = KK TO M + N
      A(I, J) = A(I, J) - A(I, K) * A(K, J) / A(K, K)
    NEXT J
  NEXT I
  NEXT K
  IF ABS(A(N, N)) < DELT THEN
    PRINT "THE MATRIX IS SINGULAR"
    EXIT SUB
  END IF
  FOR K = 1 TO M
    A(N, K + N) = A(N, K + N) / A(N, N)
    FOR IE = 1 TO N - 1
      I = N - IE
      IX = I + 1
      FOR J = IX TO N
        A(I, K + N) = A(I, K + N) - A(J, K + N) * A(I, J)
      NEXT J
      A(I, K + N) = A(I, K + N) / A(I, I)
    NEXT IE
  NEXT K
  EXIT SUB
ELSEIF ABS(A(1, 1)) < DELT THEN
  PRINT "THE MATRIX IS SINGULAR"
  EXIT SUB
END IF
FOR J = 1 TO M
  A(1, N + J) = A(1, N + J) / A(1, 1)
NEXT J
END SUB

```

```

'-----
'
'               SUBROUTINE LSQM
'
'  FUNCTION :
'      THIS SUBROUTINE COMPUTES THE COEFFICIENTS OF THE LEAST
'      SQUARES POLYNOMIAL  $P(X) = C(1) + C(2) * X + \dots + C(M+1) * X^{**M}$ 
'      FOR A SET OF FUNCTIONAL VALUES F AND DOMAIA POINTS X
'  PARAMETERS :
'  INPUT :
'      N ---> NUMBER OF POINTS (NOT GREATER THAN 1000 )

```

```

'          M ----> POLYNOMIAL DEGREE ( LESS THAN 30 )
'          X ----> N BY 1 ARRAY OF DOMAIN POINTS
'          F ----> N BY 1 ARRAY OF FUNCTION VALUES
'
'    OUTPUT :
'          C ----> M+1 BY 1 ARRAY OF COEFFICIENTS FOR THE LEAST-
'                SQUARES POLYNOMIAL
'
'    REFERENCES:
'          SIDNEY YAKOWITZ, FERENC SZIDAROVSKY, "AN INTRODUCTION
'          TO NUMERICAL COMPUTATIONS ", SECOND EDITION, 1990,
'
'-----

```

```

SUB LSQM (N, M, X(), F(), C())
DIM POWX(1000): DIM FX(1000): DIM XX(30, 31): DIM SUMPOW(100)
FOR I = 1 TO N
  POWX(I) = 1
  FX(I) = F(I)
NEXT I
XX(1, M + 2) = 0
FOR I = 1 TO N
  XX(1, M + 2) = XX(1, M + 2) + F(I)
NEXT I
SUMPOW(1) = N
FOR I = 2 TO M + 1
  SUMPOW(I) = 0
  XX(I, M + 2) = 0
  FOR J = 1 TO N
    POWX(J) = POWX(J) * X(J)
    FX(J) = FX(J) * X(J)
    SUMPOW(I) = SUMPOW(I) + POWX(J)
    XX(I, M + 2) = XX(I, M + 2) + FX(J)
  NEXT J
NEXT I
FOR I = M + 2 TO (2 * (M + 1))
  SUMPOW(I) = 0
  FOR J = 1 TO N
    POWX(J) = POWX(J) * X(J)
    SUMPOW(I) = SUMPOW(I) + POWX(J)
  NEXT J
NEXT I
FOR I = 1 TO M + 1
  FOR J = 1 TO M + 1
    XX(I, J) = SUMPOW(I + J - 1)
  NEXT J
NEXT I
N1 = M + 1
M1 = 1
ND = 30
EPS = .000001#
CALL GAUS1(N1, M1, ND, XX(), EPS)
FOR I = 1 TO M + 1
  C(I) = XX(I, M + 2)
NEXT I
END SUB

```

```

'-----
'
'          SUBROUTINE RDFILE1
'
'    THIS SUBROUTINE READ A DATA FOR OBSERVATION STATIONS , DATA
'    SHOULD BE ARRANGED IN EXTERNAL FILE , LIKE SO :
'
'    X(1)          Y(1)          Z(1)
'    X(2)          Y(2)          Z(2)
'    ...           ...           ...

```

```

'      ...      ...      ...
'      ...      ...      ...
'      X(NS)      Y(NS)      Z(NS)
'

```

```

-----
SUB RDFILE1 (ns, XS(), YS(), Z()) STATIC
PRINT "FILE NAME OF STATION DATA TO OPEN "
INPUT N1$
N2$ = ".DAT"
N$ = N1$ + N2$
OPEN "I", #1, N$
FOR I = 1 TO ns
IF EOF(1) THEN 10
INPUT #1, XS(I), YS(I), Z(I)
NEXT I
10 CLOSE
END SUB

```

```

-----
'      SUBROUTINE SORT
'
'      SORT AN ARRAY " D " OF LENGTH (NS-1) INTO ASCENDING
'      NUMERICAL ORDER , WHILE MAKING THE CORRESPONDING
'      REARRANGEMENT OF THE ARRAY HZSD.

```

```

-----
SUB SORT (M, R(), zsd())
FOR J = 1 TO M - 1
FOR I = J + 1 TO M
IF R(J) <= R(I) THEN GOTO 20
K = R(J): R(J) = R(I): R(I) = K
L = zsd(J): zsd(J) = zsd(I): zsd(I) = L
20 NEXT I
NEXT J
END SUB

```

```

SUB WRFILE (N, D(), CSV(), K$) STATIC

```

```

-----
'      SUBROUTINE WRFILE
'
'      THIS SUBROUTINE WRITE A DATA , DATA SHOULD BE
'      ARRANGED IN EXTERNAL FILE , LIKE SO :
'      D(1)      CSV(1)
'      D(2)      CSV(2)
'      ....      ....
'      ....      ....
'
'      .....      ....
'      D(M)      CSV(M)
'

```

```

-----
      OPEN "O", #1, K$
      FOR I = 1 TO N
      IF CSV(I) = 0 THEN 88
      PRINT #1, D(I), CSV(I)
88      NEXT I
      CLOSE #1
END SUB

```

```

      SUBROUTINE WRFILE1
      '
      ' THIS SUBROUTINE WRITE A DATA , DATA SHOULD BE
      ' ARRANGED IN EXTERNAL FILE , LIKE SO :
      ' X(1)      Y(1)      RS(1)
      ' X(2)      Y(2)      RS(2)
      ' .....
      ' .....
      '
      ' .....
      ' Z(NS)      X(NS)      RS(NS)
      '

```

```

-----
SUB WRFILE1 (ns, XS(), YS(), RS(), KS)
  OPEN "O", #1, KS
  FOR I = 1 TO ns
    PRINT #1, XS(I), YS(I), INT(RS(I))
  NEXT I
  CLOSE #1
END SUB

```

```

-----
      SUBROUTINE ZSQD
      '
      ' COMPUTE THE HALF-SQUARD DIFFERENCES BETWEEN THE DATA VALUE
      ' AT THE ONE STATION AND ALL OTHER STATIONS.
      '
      -----
SUB ZSQD (I, ns, Z(), zsd())
  SUM = 0
  FOR J = 1 TO ns
    IF I = J THEN 1001
    SUM = SUM + 1
    zsd(SUM) = ((Z(I) - Z(J)) ^ 2) / 2
  1001 NEXT J
END SUB

```

SCM

```

DECLARE SUB RDFILE2 (IMAX!, jMAX!, Z!())
DECLARE SUB ERRORF (NS!, DS!, IMAX!, jMAX!, XS!(), YS!(), Z!(),
Z0!(), E!())
DECLARE SUB CORREC (NS!, D!, DS!, I!, J!, XS!(), YS!(), ALFA!,
E!(), WC!)
DECLARE SUB RDFILE1 (NS!, XS!(), YS!(), Z0!())
DECLARE SUB WRFILE (IMAX!, jMAX!, DS!, Z!())

```

SCM

THIS PROGRAM CONSTRUCT THE FIELDS " GRID POINTS " OF
METEOROLOGICAL QUANTITIES ON BASIS OF OBSERVATIONAL
DATA.

THE TECHNIQUES OF OBJECTIVE USED IN THIS PROGRAM IS
SUCCESSIVE CORRECTION METHOD.

INPUTS REQUIRED :

NS-----> NUMBER OF OBSERVING STATIONS.
Z0-----> ARRAY OF MET. PARAMETERS AT
STATIONO
Z-----> ARRAY OF MET. PARAMETERS AT
GRID POINTS (FIRST GUESS)

OUTPUTS :

Z-----> ARRAY OF MET. PARAMETERS AT TIME
ANALYSIS.
X-----> LOCATION OF GRID IN X-COORDINATE
Y-----> LOCATION OF GRID IN Y-COORDINATE

```

CLS
NS = 47: IMAX = 9: jMAX = 7: d1 = 3
DMAX = 1400: SCAN = 4: ALFA = 2: A = 6370: pi = 3.14159
DIM STNO(NS): DIM LAT(NS): DIM LON(NS): DIM Z0(NS): DIM
Z(IMAX, jMAX)
DIM XS(NS): DIM YS(NS): DIM E(NS)
DS = (2 * pi * A / 360) * d1
AREA = ((IMAX - 1) * DS) * ((jMAX - 1) * DS)
DMIN = SQR(AREA / NS)
DD = (DMAX - DMIN) / SCAN
CALL RDFILE1(NS, XS(), YS(), Z0())
CALL RDFILE2(IMAX, jMAX, Z())
FOR L = 0 TO SCAN - 1
D = DMAX - DD * L
CALL ERRORF(NS, DS, IMAX, jMAX, XS(), YS(), Z(), Z0(), E())
FOR I = 1 TO IMAX
FOR J = 1 TO jMAX
CALL CORREC(NS, D, DS, I, J, XS(), YS(), ALFA, E(), WC)
Z(I, J) = Z(I, J) + WC
NEXT J

```

```

NEXT I
NEXT L
      CALL WRFILE(IMAX, jMAX, DS, Z())
END

```

```

SUB CORREC (NS, D, DS, I, J, XS(), YS(), ALFA, E(), WC)
  IN = 0
  WC = 0
  FOR k = 1 TO NS
    X = XS(k) - (I - 1) * DS
    Y = YS(k) - (J - 1) * DS
    R = SQR(X * X + Y * Y)
    IF R <= D THEN
      IN = IN + 1
      W = (ABS((R * R - D * D) / (R * R + D * D))) ^ ALFA
      WC = WC + W * E(k)
    END IF
  NEXT k
  IF IN > 0 THEN WC = WC / IN
END SUB

```

```

SUB ERRORF (NS, DS, IMAX, jMAX, XS(), YS(), Z(), Z0(), E())
  FOR k = 1 TO NS
    J = INT(YS(k) / DS + 1)
    I = INT(XS(k) / DS + 1)
    X = XS(k) - ((I - 1) * DS)
    Y = YS(k) - ((J - 1) * DS)
    V = (Z(I + 1, J + 1) - Z(I, J + 1)) * X / DS + Z(I, J + 1)
    B = (Z(I + 1, J) - Z(I, J)) * X / DS + Z(I, J)
    ZPQR = (V - B) * Y / DS + B
    E(k) = Z0(k) - ZPQR
  NEXT k
END SUB

```

```

SUB RDFILE1 (NS, XS(), YS(), Z0()) STATIC
PRINT "FILE NAME OF STATION DATA TO OPEN "
INPUT N1$
N2$ = ".DAT"
N$ = N1$ + N2$
OPEN "I", #1, N$
FOR I = 1 TO NS
IF EOF(1) THEN 10
INPUT #1, XS(I), YS(I), Z0(I)
NEXT I
10 CLOSE
END SUB

```

```

SUB RDFILE2 (IMAX, jMAX, Z()) STATIC
PRINT "FILE NAME OF GRID DATA TO OPEN "
INPUT M1$
PRINT "                                     ( PLEASE WAIT )"
M2$ = ".DAT"
M$ = M1$ + M2$
OPEN "I", #1, M$
FOR J = 1 TO jMAX
FOR I = 1 TO IMAX
IF EOF(1) THEN 11
INPUT #1, WW, WW, Z(I, J)
NEXT I

```

```

        NEXT J
11      CLOSE #1
END SUB

```

```

SUB WRFILE (IMAX, jMAX, DS, Z()) STATIC
  PRINT "FILE NAME OF RESULT TO CREAT "
  INPUT k1$
  k2$ = ".dat"
  k$ = k1$ + k2$
  OPEN "O", #1, k$
  FOR J = 1 TO jMAX
    FOR I = 1 TO IMAX
      Z(I, J) = INT(Z(I, J) + .5)
      XG = INT((I - 1) * DS + .5)
      YG = INT((J - 1) * DS + .5)
      PRINT #1, XG, YG, Z(I, J)
      PRINT XG, YG, Z(I, J)
    NEXT I
  NEXT J
  CLOSE #1
END SUB

```

MSCM

```

DECLARE SUB RDFILE3 (IMAX!, JMAX!, RG!())
DECLARE SUB RDFILE2 (IMAX!, JMAX!, Z!())
DECLARE SUB ERRORF (NS!, DS!, IMAX!, JMAX!, XS!(), YS!(), Z!(),
Z0!(), E!())
DECLARE SUB CORREC (NS!, D!, DS!, I!, J!, XS!(), YS!(), ALFA!,
E!(), WC!)
DECLARE SUB RDFILE1 (NS!, XS!(), YS!(), Z0!())
DECLARE SUB WRFILE (IMAX!, JMAX!, DS!, Z!())

```

THIS PROGRAM CONSTRUCT THE FIELDS " GRID POINTS "OF
METEOROLOGICAL QUANTITIES ON BASIS OF OBSERVATIONAL
DATA.

THE TECHNIQUES OF OBJECTIVE USED IN THIS PROGRAM IS
MODIFICATION OF SUCCESSIVE CORRECTION METHOD.

INPUTS REQUIRED :

NS-----> NUMBER OF OBSERVING STATIONS.
Z0-----> ARRAY OF MET. PARAMETERS AT
STATIONS
Z-----> ARRAY OF MET. PARAMETERS AT
GRID POINTS (FIRST GUESS)
RG-----> RADIUS OF INFLUENCE AT GRID POINTS

OUTPUTS :

Z-----> ARRAY OF MET. PARAMETERS AT TIME
ANALYSIS.
X-----> LOCATION OF GRID IN X-COORDINATE
Y-----> LOCATION OF GRID IN Y-COORDINATE

CLS

NS = 47: IMAX = 9: JMAX = 7: d1 = 3

ALFA = 2: A = 6370: pi = 3.14159

DIM STNO(NS): DIM LAT(NS): DIM LON(NS): DIM Z0(NS): DIM
Z(IMAX, JMAX)

DIM XS(NS): DIM YS(NS): DIM E(NS): DIM RG(IMAX, JMAX)

DS = (2 * pi * A / 360) * d1

CALL RDFILE1(NS, XS(), YS(), Z0())

CALL RDFILE2(IMAX, JMAX, Z())

CALL RDFILE3(IMAX, JMAX, RG())

CALL ERRORF(NS, DS, IMAX, JMAX, XS(), YS(), Z(), Z0(), E())

FOR I = 1 TO IMAX

FOR J = 1 TO JMAX

D = RG(I, J)

CALL CORREC(NS, D, DS, I, J, XS(), YS(), ALFA, E(), WC)

Z(I, J) = Z(I, J) + WC

NEXT J

NEXT I

CALL WRFILE(IMAX, JMAX, DS, Z())

END

```

SUB CORREC (NS, D, DS, I, J, XS(), YS(), ALFA, E(), WC)
  IN = 0
  WC = 0
  FOR k = 1 TO NS
    X = XS(k) - (I - 1) * DS
    Y = YS(k) - (J - 1) * DS
    R = SQR(X * X + Y * Y)
    IF R <= D THEN
      IN = IN + 1
      W = (ABS((R * R - D * D) / (R * R + D * D))) ^ ALFA
      WC = WC + W * E(k)
    END IF
  NEXT k
  IF IN > 0 THEN WC = WC / IN
END SUB

```

```

-----
SUB ERRORF (NS, DS, IMAX, JMAX, XS(), YS(), Z(), Z0(), E())
  FOR k = 1 TO NS
    J = INT(YS(k) / DS + 1)
    I = INT(XS(k) / DS + 1)
    X = XS(k) - ((I - 1) * DS)
    Y = YS(k) - ((J - 1) * DS)
    V = (Z(I + 1, J + 1) - Z(I, J + 1)) * X / DS + Z(I, J + 1)
    B = (Z(I + 1, J) - Z(I, J)) * X / DS + Z(I, J)
    ZPQR = (V - B) * Y / DS + B
    E(k) = Z0(k) - ZPQR
  NEXT k
END SUB

```

```

-----
SUB RDFILE1 (NS, XS(), YS(), Z0()) STATIC
  PRINT "FILE NAME OF STATION DATA TO OPEN "
  INPUT N1$
  N2$ = ".DAT"
  N$ = N1$ + N2$
  OPEN "I", #1, N$
  FOR I = 1 TO NS
    IF EOF(1) THEN 10
    INPUT #1, XS(I), YS(I), Z0(I)
  NEXT I
  10 CLOSE
END SUB

```

```

-----
SUB RDFILE2 (IMAX, JMAX, Z()) STATIC
  PRINT "FILE NAME OF GRID DATA TO OPEN "
  INPUT M1$
  PRINT "                                     ( PLEASE WAIT )"
  M2$ = ".DAT"
  M$ = M1$ + M2$
  OPEN "I", #1, M$
  FOR J = 1 TO JMAX
    FOR I = 1 TO IMAX
      IF EOF(1) THEN 11
      INPUT #1, WW, WW, Z(I, J)
    NEXT I
  NEXT J
  11 CLOSE #1
END SUB

```

```

'-----
SUB RDFILE3 (IMAX, JMAX, RG())
  OPEN "I", #1, "RG.DAT"
  FOR J = 1 TO JMAX
    FOR I = 1 TO IMAX
      IF EOF(1) THEN 111
      INPUT #1, BB, PP, RG(I, J)
    NEXT I
  NEXT J
111  CLOSE #1
END SUB

```

```

'-----
SUB WRFILE (IMAX, JMAX, DS, Z()) STATIC
  PRINT "FILE NAME OF RESULT TO CREAT "
  INPUT k1$
  k2$ = ".dat"
  k$ = k1$ + k2$
  OPEN "O", #1, k$
  FOR J = 1 TO JMAX
    FOR I = 1 TO IMAX
      Z(I, J) = INT(Z(I, J) + .5)
      XG = INT((I - 1) * DS + .5)
      YG = INT((J - 1) * DS + .5)
      PRINT #1, XG, YG, Z(I, J)
    NEXT I
  NEXT J
  CLOSE #1
END SUB

```

CROSS VALIDATION FOR SCM

```

DECLARE SUB RDFILE2 (IMAX!, jMAX!, Z!())
DECLARE SUB CORREC (NS!, D!, I!, XS!(), YS!(), ALFA!, E!(), WC!)
DECLARE SUB RDFILE1 (NS!, XS!(), YS!(), Z0!())
DECLARE SUB ERROR2 (NS!, Z0!(), Z1!(), E!())
DECLARE SUB ERROR1 (NS!, DS!, IMAX!, jMAX!, XS!(), YS!(), Z!(),
Z0!(), Z1!(), E!())
DECLARE SUB STATISTIC (NS!, Z0!(), Z1!(), E!())

```

CROSS VALIDATION FOR SCM

INPUTS REQUIRED :

```

NS-----> NUMBER OF OBSERVING STATIONS.
Z0-----> ARRAY OF MET. PARAMETERS AT
            STATIONO
Z-----> ARRAY OF MET. PARAMETERS AT
            GRID POINTS (FIRST GUESS)

```

```

CLS
NS = 47: IMAX = 9: jMAX = 7: d1 = 3
DMAX = 1400: SCAN = 4: ALFA = 2: A = 6370: pi = 3.14159
DIM STNO(NS): DIM LAT(NS): DIM LON(NS): DIM Z0(NS): DIM
Z(IMAX, jMAX)
DIM XS(NS): DIM YS(NS): DIM E(NS): DIM Z1(NS)
DS = (2 * pi * A / 360) * d1
AREA = ((IMAX - 1) * DS) * ((jMAX - 1) * DS)
DMIN = SQR(AREA / NS)
DD = (DMAX - DMIN) / SCAN
      CALL RDFILE1(NS, XS(), YS(), Z0())
      CALL RDFILE2(IMAX, jMAX, Z())
FOR L = 0 TO SCAN - 1
  D = DMAX - DD * L
  IF L = 0 THEN
    CALL ERROR1(NS, DS, IMAX, jMAX, XS(), YS(), Z(), Z0(), Z1(),
    E())
  ELSE
    CALL ERROR2(NS, Z0(), Z1(), E())
  END IF
  FOR I = 1 TO NS
    CALL CORREC(NS, D, I, XS(), YS(), ALFA, E(), WC)
    Z1(I) = Z1(I) + WC
25  NEXT I
    NEXT L
      CALL STATISTIC(NS, Z0(), Z1(), E())
END

```

```

SUB CORREC (NS, D, I, XS(), YS(), ALFA, E(), WC)
  IN = 0
  WC = 0

```

```

      FOR K = 1 TO NS
      IF K = I THEN 100
      X = XS(K) - XS(I)
      Y = YS(K) - YS(I)
      R = SQR(X * X + Y * Y)
      IF R <= D THEN
      IN = IN + 1
      W = (ABS((R * R - D * D) / (R * R + D * D))) ^ ALFA
      WC = WC + W * E(K)
      END IF
100  NEXT K
      IF IN > 0 THEN WC = WC / IN
END SUB

```

```

SUB ERROR1 (NS, DS, IMAX, jMAX, XS(), YS(), Z(), Z0(), Z1(), E())
  FOR K = 1 TO NS
    J = INT(YS(K) / DS + 1)
    I = INT(XS(K) / DS + 1)
    X = XS(K) - ((I - 1) * DS)
    Y = YS(K) - ((J - 1) * DS)
    V = (Z(I + 1, J + 1) - Z(I, J + 1)) * X / DS + Z(I, J + 1)
    B = (Z(I + 1, J) - Z(I, J)) * X / DS + Z(I, J)
    ZPQR = (V - B) * Y / DS + B
    Z1(K) = ZPQR
    E(K) = Z0(K) - ZPQR
  NEXT K
END SUB

```

```

SUB ERROR2 (NS, Z0(), Z1(), E())
  FOR K = 1 TO NS
    E(K) = Z0(K) - Z1(K)
  NEXT K
END SUB

```

```

SUB RDFILE1 (NS, XS(), YS(), Z0()) STATIC
  PRINT "FILE NAME OF STATION DATA TO OPEN "
  INPUT N1$
  N2$ = ".DAT"
  N$ = N1$ + N2$
  OPEN "I", #1, N$
  FOR I = 1 TO NS
    IF EOF(1) THEN 10
    INPUT #1, XS(I), YS(I), Z0(I)
  NEXT I
10 CLOSE
END SUB

```

```

SUB RDFILE2 (IMAX, jMAX, Z()) STATIC
  PRINT "FILE NAME OF GRID DATA TO OPEN "
  INPUT M1$
  PRINT "                                     ( PLEASE WAIT )"
  M2$ = ".DAT"
  M$ = M1$ + M2$
  OPEN "I", #1, M$
  FOR J = 1 TO jMAX
    FOR I = 1 TO IMAX
      IF EOF(1) THEN 11
      INPUT #1, WW, WW, Z(I, J)
    NEXT I
  NEXT J
11

```

```
      NEXT J
11    CLOSE #1
END SUB
```

```
SUB STATISTIC (NS, Z0(), Z1(), E())
  CLS
  SUM = 0
  FOR I = 1 TO NS
    E(I) = Z1(I) - Z0(I)
    SUM = E(I) ^ 2 + SUM
  NEXT I
  MSE = SUM / NS
  PRINT "MSE = ", MSE
END SUB
```

CROSS VALIDATION FOR MSCM

```

DECLARE SUB STATISTIC (NS!, Z0!(), Z1!(), E!())
DECLARE SUB CORREC (NS!, D!, i!, XS!(), YS!(), ALFA!, E!(), WC!)
DECLARE SUB RDFILE3 (NS!, RG!())
DECLARE SUB RDFILE2 (IMAX!, JMAX!, Z!())
DECLARE SUB RDFILE1 (NS!, XS!(), YS!(), Z0!())
DECLARE SUB ERROR1 (NS!, DS!, IMAX!, JMAX!, XS!(), YS!(), Z!(),
Z0!(), Z1!(), E!())

```

CROSS VALIDATION FOR MSCM

INPUTS REQUIRED :

```

NS-----> NUMBER OF OBSERVING STATIONS.
Z0-----> ARRAY OF MET. PARAMETERS AT
            STSTATIONS
Z-----> ARRAY OF MET. PARAMETERS AT
            GRID POINTS (FIRST GUESS)
RS-----> RADIUS OF INFLUENCE AT STATION

```

```

CLS
NS = 47: IMAX = 9: JMAX = 7: d1 = 3
ALFA = 2: A = 6370: pi = 3.14159
DIM STNO(NS): DIM LAT(NS): DIM LON(NS): DIM Z0(NS): DIM
Z(IMAX, JMAX)
DIM XS(NS): DIM YS(NS): DIM E(NS): DIM Z1(NS): DIM RS(NS)
DS = (2 * pi * A / 360) * d1
      CALL RDFILE1(NS, XS(), YS(), Z0())
      CALL RDFILE2(IMAX, JMAX, Z())
      CALL RDFILE3(NS, RS())
CALL ERROR1(NS, DS, IMAX, JMAX, XS(), YS(), Z(), Z0(), Z1(),
E())
FOR i = 1 TO NS
D = RS(i)
      CALL CORREC(NS, D, i, XS(), YS(), ALFA, E(), WC)
Z1(i) = Z1(i) + WC
25 NEXT i
      CALL STATISTIC(NS, Z0(), Z1(), E())
END

```

```

SUB CORREC (NS, D, i, XS(), YS(), ALFA, E(), WC)
IN = 0
WC = 0
FOR K = 1 TO NS
IF K = i THEN 100
X = XS(K) - XS(i)
Y = YS(K) - YS(i)
R = SQR(X * X + Y * Y)
IF R <= D THEN
IN = IN + 1
W = (ABS((R * R - D * D) / (R * R + D * D))) ^ ALFA

```

```

        WC = WC + W * E(K)
    END IF
100    NEXT K
        IF IN > 0 THEN WC = WC / IN
END SUB

```

```

'-----
SUB ERROR1 (NS, DS, IMAX, JMAX, XS(), YS(), Z(), Z0(), Z1(), E())
    FOR K = 1 TO NS
        J = INT(YS(K) / DS + 1)
        i = INT(XS(K) / DS + 1)
        X = XS(K) - ((i - 1) * DS)
        Y = YS(K) - ((J - 1) * DS)
        V = (Z(i + 1, J + 1) - Z(i, J + 1)) * X / DS + Z(i, J + 1)
        B = (Z(i + 1, J) - Z(i, J)) * X / DS + Z(i, J)
        ZPQR = (V - B) * Y / DS + B
        Z1(K) = ZPQR
        E(K) = Z0(K) - ZPQR
    NEXT K
END SUB

```

```

'-----
SUB ERROR2 (NS, Z0(), Z1(), E())
    FOR K = 1 TO NS
        E(K) = Z0(K) - Z1(K)
    NEXT K
END SUB

```

```

'-----
SUB RDFILE1 (NS, XS(), YS(), Z0()) STATIC
    PRINT "FILE NAME OF STATION DATA TO OPEN "
    INPUT N1$
    N2$ = ".DAT"
    N$ = N1$ + N2$
    OPEN "I", #1, N$
    FOR i = 1 TO NS
        IF EOF(1) THEN 10
        INPUT #1, XS(i), YS(i), Z0(i)
    NEXT i
10    CLOSE
END SUB

```

```

'-----
SUB RDFILE2 (IMAX, JMAX, Z()) STATIC
    PRINT "FILE NAME OF GRID DATA TO OPEN "
    INPUT M1$
    PRINT "                                     ( PLEASE WAIT )"
    M2$ = ".DAT"
    M$ = M1$ + M2$
    OPEN "I", #1, M$
    FOR J = 1 TO JMAX
        FOR i = 1 TO IMAX
            IF EOF(1) THEN 11
            INPUT #1, WW, WW, Z(i, J)
        NEXT i
    NEXT J
11    CLOSE #1
END SUB

```

```

'-----
SUB RDFILE3 (NS, RG())
    OPEN "I", #1, "RS.DAT"
    FOR i = 1 TO NS

```

```
        IF EOF(1) THEN 111
        INPUT #1, BB, PP, RG(i)
        NEXT i
111    CLOSE #1
END SUB
```

```
SUB STATISTIC (NS, Z0(), Z1(), E())
    CLS
    SUM = 0
    FOR i = 1 TO NS
        E(i) = Z1(i) - Z0(i)
        SUME = ABS(E(i)) + SUME
        SUM = E(i) ^ 2 + SUM
    NEXT i
    MSE = SUM / NS
    PRINT "MSE = ", MSE
END SUB
```

CONVERT XYZ DATA FILE FORMAT TO SURFER GRID

```

DECLARE SUB WRFILE (IMAX!, JMAX!, XG!(), YG!(), Z!(), zmax!, zmin!)
DECLARE SUB RDFILE (IMAX!, JMAX!, XG!(), YG!(), Z!())
DECLARE SUB MAXMIN (IMAX!, JMAX!, Z!(), zmax!, zmin!)

```

```

'-----
'  THIS PROGRAM CONVERT XYZ DATA FILE FORMAT (.DAT) TO SURFER GRID
'  FILE (.GRD)
'-----

```

```

CLS
X$ = STRING$(80, " ")
FOR I = 1 TO 25
PRINT X$
NEXT I
PRINT " THIS PROGRAM CONVERT XYZ DATA FILE FORMAT (.DAT) TO SURFER
GRID FILE (.GRD) "
LOCATE 3, 30: PRINT " BY : ZIYAD Z.HABIB ": PRINT : PRINT : PRINT
PRINT "IMAX"
INPUT IMAX
PRINT "JMAX"
INPUT JMAX
DIM XG(IMAX, JMAX): DIM YG(IMAX, JMAX): DIM Z(IMAX, JMAX)
CALL RDFILE(IMAX, JMAX, XG(), YG(), Z())
CALL MAXMIN(IMAX, JMAX, Z(), zmax, zmin)
CALL WRFILE(IMAX, JMAX, XG(), YG(), Z(), zmax, zmin)
CLS
END

```

```

'-----
SUB MAXMIN (IMAX, JMAX, Z(), zmax, zmin)
zmax = Z(1, 1): zmin = Z(1, 1)
FOR j = 1 TO JMAX: FOR I = 1 TO IMAX
IF zmax < Z(I, j) THEN zmax = Z(I, j): REM
IF zmin > Z(I, j) THEN zmin = Z(I, j): REM
NEXT I, j
END SUB

```

```

'-----
SUB RDFILE (IMAX, JMAX, XG(), YG(), Z()) STATIC
PRINT "FILE NAME TO OPEN ( .DAT ) "
INPUT k1$
k2$ = ".dat"
k$ = k1$ + k2$
OPEN "I", #1, k$
FOR j = 1 TO JMAX
FOR I = 1 TO IMAX
INPUT #1, XG(I, j), YG(I, j), Z(I, j)
NEXT I
NEXT j
CLOSE #1
END SUB

```

```

'-----
SUB WRFILE (IMAX, JMAX, XG(), YG(), Z(), zmax, zmin) STATIC
PRINT "FILE NAME OF RESULT TO CREAT ( .GRD ) "
INPUT k1$
k2$ = ".GRD"
k$ = k1$ + k2$

```

```
OPEN "O", #1, ks
PRINT #1, "DSAA"
PRINT #1, IMAX; JMAX
PRINT #1, XG(1, 1); XG(IMAX, 1)
PRINT #1, YG(1, 1); YG(1, JMAX)
PRINT #1, zmax; zmin
FOR j = 1 TO JMAX
  INDEX = 10
  FOR I = 1 TO IMAX
    PRINT #1, Z(I, j);
    IF I = INDEX THEN
      PRINT #1,
      INDEX = INDEX + 10
    END IF
  NEXT I
  PRINT #1,
  PRINT #1,
  NEXT j
  CLOSE #1
END SUB
```

CURRICULUM VITAE

Zeyad Zenabddin Habib was born in Tripoli, Libya on June 2, 1960, completed secondary education in Tripoli, Libya. In 1980 he began his undergraduate study in Department of Meteorology, Faculty of Science, University of Al-fateh, and he received the degree of Bachelor of Science in 1984.

Since 1984, he working as Demonstrator in Department of Meteorology, Faculty of Science, University of Al-fateh in Tripoli, Libya.

