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Scientific Notebook #126
Supporting the Regional
Hydrology Research Project

Issued To: Gordon Wittmeyer
CNWRA
210-522-5082 [signature] 12/28/95

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Subject: **SCIENTIFIC NOTEBOOK No. 126 / 127**
Date: Fri, 25 Aug 2000 12:24:42 -0500
From: Bruce Mabrito <bmabrito@gargol.cnwra.swri.edu>
Organization: CNWRA
To: Maria Padilla <mjpadilla@gargol.cnwra.swri.edu>, "Bruce Mabrito (bmabrito)" <bmabrito@gargol.cnwra.swri.edu>, "English Pearcy (epearcy)" <epearcy@gargol.cnwra.swri.edu>, "David Pickett (dpickett)" <dpickett@gargol.cnwra.swri.edu>, "James Prikryl (jprikryl)" <jprikryl@gargol.cnwra.swri.edu>

The purpose of this e-mail message is to document the location of scientific notebook number 127.

First, scientific notebook 126 was issued to Gordon Wittmeyer on 12/8/1994. That notebook was utilized and then returned to QA Records 2/22/1996.

During the August 2000 call for scientific notebooks, another scientific notebook, also numbered 126, was returned. It has been determined that QA "double issued" the number 126. Apparently, I issued No. 126 to Gordon Wittmeyer in 1994 and Alice Cortinas (Records Custodian) issued a second scientific notebook with the same number 126 on 12/21/1994 to Jim Prikryl. In the call for notebooks, we discovered this fact. We had assumed that scientific notebook No. 127 was lost and a memorandum was issued from Dr. English Pearcy on June 15, 2000 so stating. It is very clear that this notebook should have been identified number 127 because all other identifying information (issuer, receiver of notebook, dates, and project numbers) otherwise match well

The following actions are being taken. A B. Mabrito signed copy of this e-mail message will be attached to the E. Pearcy memo of 6/15/2000 and also to the scientific notebook issued to Jim Prikryl. Second, the number 126 on the front of Jim Prikryl's notebook (which is now being used by Dr. David Pickett) will be changed to number 127 and initialed and dated by B. Mabrito. The Scientific Log Notebook will be corrected to reflect that scientific notebook No. 127 was not lost and is now in use by Dr. David Pickett.

[signature] 8/25/2000
Bruce Mabrito

December 8, 1994.

Goal: Produce a kriged map of mean annual precipitation for the Death Valley region.

Procedure: Ordinary kriging with an extended or exterior variable drift model. Drift model is first order, and based on elevation.

Elevation → precip model; drift model

1000 ln (AAP) = a + b (elevation)

AAP = average annual precip

Elevation data comes from USGS 1 degree DEM

1. Each 1° X 1° area is divided into a 1201 X 1201 grid of elevations (in meters) spaced 3 arc-secs apart.
2. Read each DEM file into EarthVision (EV).
3. Convert each to a 1201 X 1201 EV 2D grid.
4. Reduce grid density
5. Create Union of 1° X 1° reduced grids
6. Export union grid to ASCII file
7. Convert ASCII geometric coords to UTM

1°X1° DEM's (/usr4/gwitt/Ischyetal/*.zgrds)

a. caliente west: caliente-w : cal_w.zgrd
b. goldfield east: goldfield-e : gold_e.zgrd
c. goldfield west: goldfield-w : gold_w.zgrd
d. lasvegas west: las_vegas-w : lv_w.zgrd
e. deathvalley east: death_valley-e : dv_e.zgrd
f. deathvalley west: death_valley-w: dv_w.zgrd

Use EV's "Utilities" (on performer)
→ Import DEM
→ convert to *.zgrd

Next step is to reduce the grid density of each of the above from 1201 x 1201 to 101 x 101 using the "formula processor" utility under "Utilities" (function "refgrd")

cal_w_small.zgrd = refgrd(cal_w.zgrd, 101, 101, -417600, -414000, 133200, 136800)

gold_e_small.zgrd = refgrd(gold_e.zgrd, 101, 101, -421200, -417600, 133200, 136800)

gold_w_small.zgrd = refgrd(gold_w.zgrd, 101, 101, -424800, -421200, 133200, 136800)

lv_w_small.zgrd = refgrd(lv_w.zgrd, 101, 101, -417600, -414000, 129600, 133200)

dv_e_small.zgrd = refgrd(dv_e.zgrd, 101, 101, -421200, -417600, 129600, 133200)

dv_w_small.zgrd = refgrd(dv_w.zgrd, 101, 101, -424800, -421200, 129600, 133200)

Next step is to combine the six *small.zgrd grids into one grid using the formula processor. We use the function "union"

small1.zgrd = union(calw_small.zgrd, gold_e_small.zgrd)

small2.zgrd = union(small1.zgrd, gold_w_small.zgrd)

small3.zgrd = union(lv_w_small.zgrd, dv_e_small.zgrd)

small4.zgrd = union(small3.zgrd, dv_w_small.zgrd)

small.zgrd = union(small2.grd, small4.zgrd)

↑ this is the coarse elevation grid file for

-115°W to -118 W & 36°N to 38°N

Next step is to convert small.zgrd to an ASCII X, Y, Z file using the "ev_export" utility

% ev_export -o small.dat small.zgrd

small.dat is ~ 2.8 Mb on /usr4/gwitt/Ischyetal

Next we need to convert small.dat so that the X,Y coordinates are in UTM rather than Latitude - Longitude. (small.dat is 301 X 201)

1. Copy small.dat to ~~small-2.dat~~ small.map GW 12/8/94

Format of small.map is

X (Arc Sec), Y (Arc Sec), Z (elev. meters), column, row.

2. Because small.map is in arc-sec, a small program was developed to convert the Lat-Long to decimal degrees. This file is called

"small.out" → X (dec. deg.), Y (dec. deg.), Z (elevation in m)

3. Evenden's Cartographic projection procedure for UNIX machines was to convert the X, Y coordinates in "small.out" to UTM. The resulting file is "small.utm"

X (meters (utm), Y (meters (utm)), Z (elev, m)

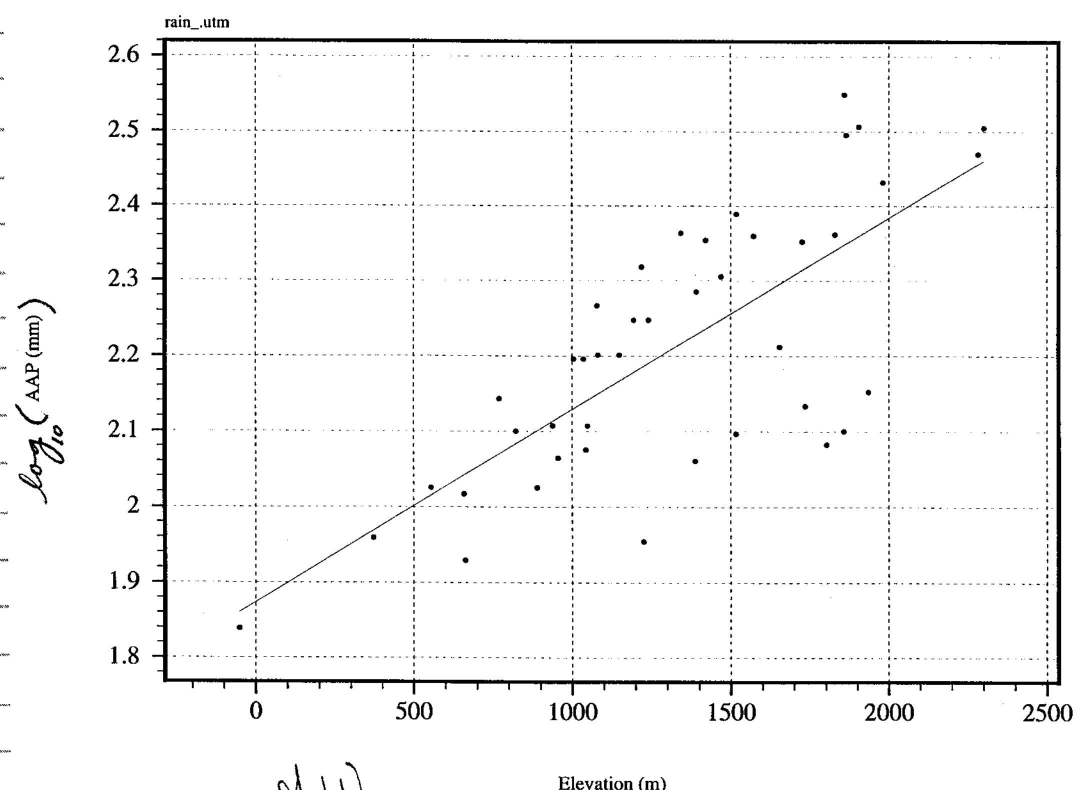
~~Script used is shown below~~ GW 12/8/94

Gordon Wittmeyer

12/12/94

Precipitation data for the Death Valley region were obtained from Hevesi et al. (1992) and entered into the computer. The coordinates of the precip stations in Hevesi et al. were given in Nevada state plane coordinates. However, the coordinates for these same stations were given in French (1983) in Longitude - Latitude. These Long-Lat were then converted to UTM coordinates using Evenden's cartographic projection program.

The logarithm of ~~Ann~~ Average Annual Precipitation was regressed on elevation in meters to obtain an external drift model. GW 12/12/94



GW

The drift model is:

$\ln(AAP) = 4.3146 + .0005872\,E$

AAP: Average Annual Precip (mm)
E: Elevation above MSL in meters.
ln: log base e.

Gordon Wittmeyer

12/13/94

Variograms for ln(AAP) and for $\ln(AAP) - (4.3146 + .0005872E)$ (the residual AAP are shown attached.

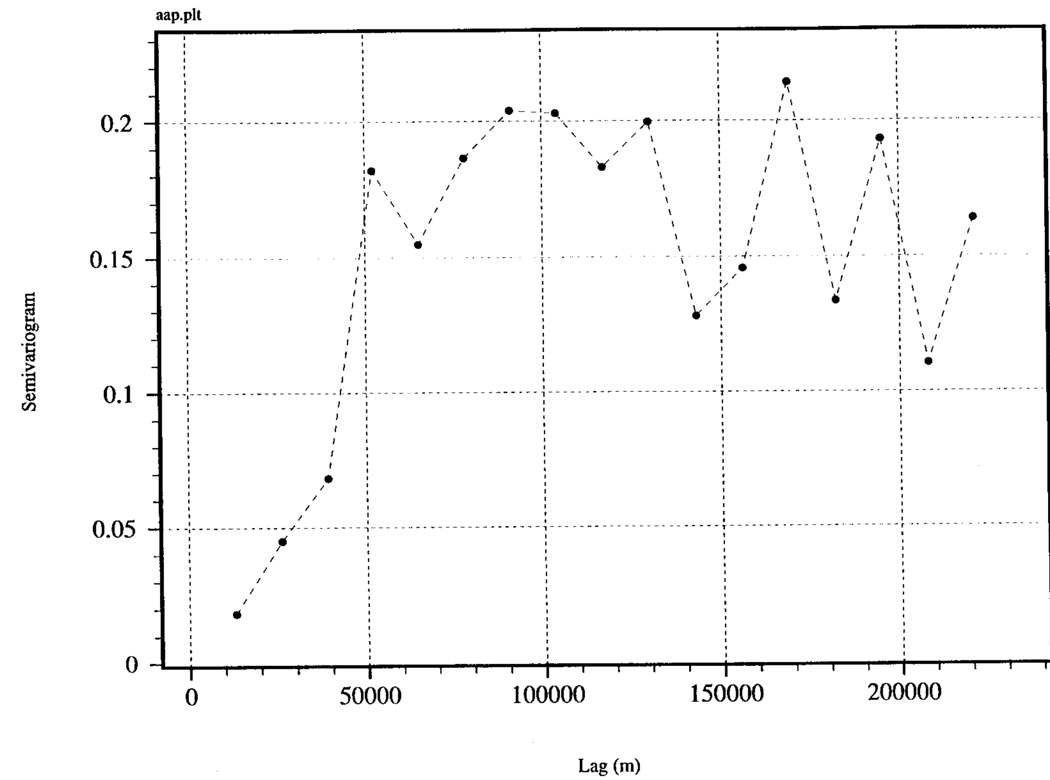
① γ for ln(AAP) appears to be stationary which is confusing since AAP is presumed to be a function of elevation and the variogram of elevation developed by Henesi et al. (1992) showed a definite lack of stationarity.

② γ for residual ln(AAP). Omni-directional γ is apparently non-stationary.

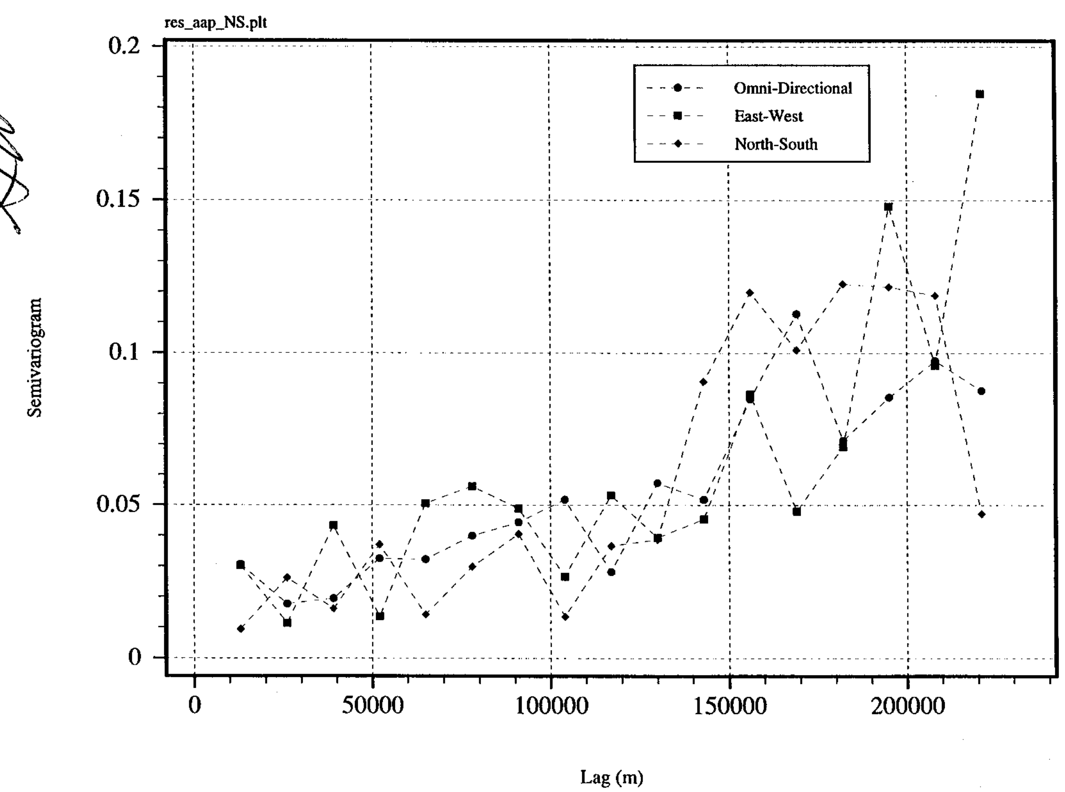
③ Other directional γ's for residual ln(AAP)

④ Directional γ's for residual ln(AAP). NE-SW & NW-SE directions appear to be principal directions. However γ(NE-SW) is clearly not stationary ... or if it is, its correlation length is very large (~200,000 m).

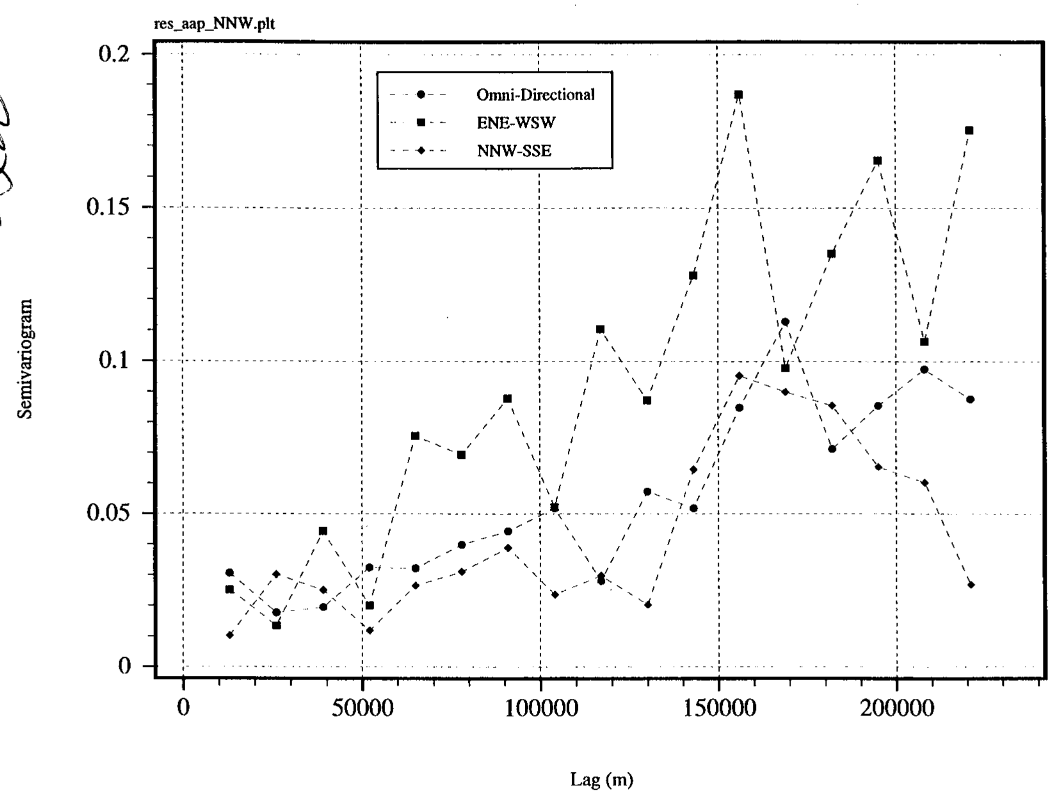
Sample Semivariogram for ln(AAP) ①



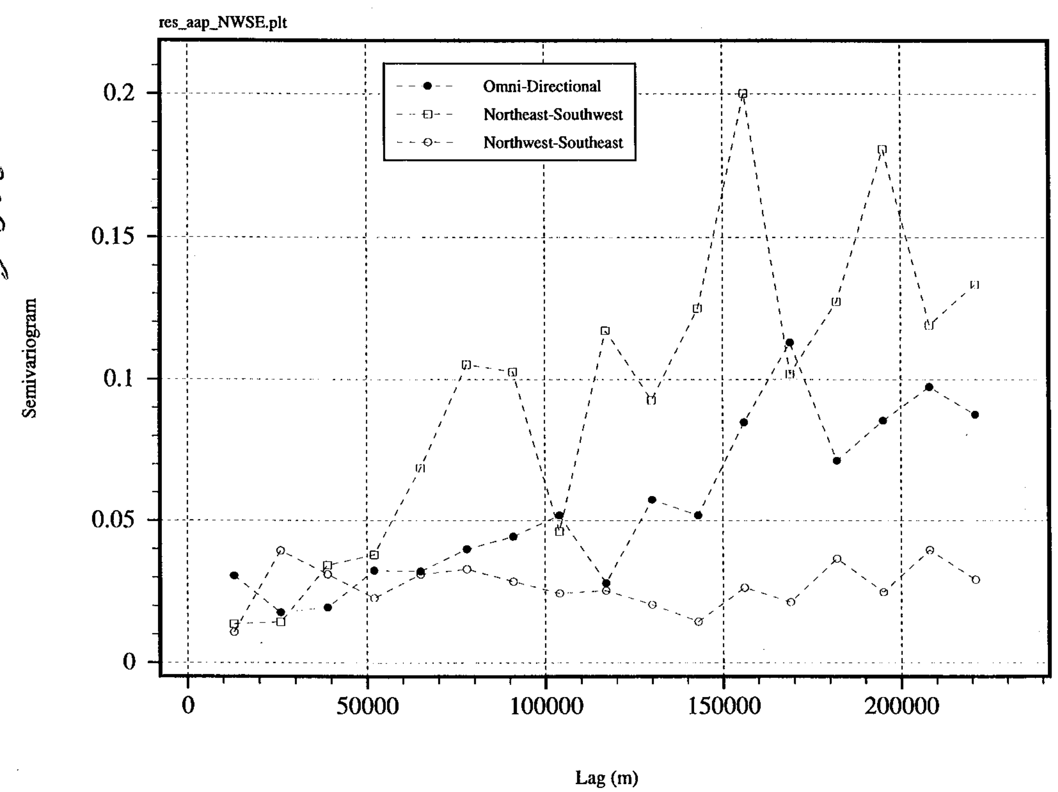
Sample Semivariogram for Residual ln(AAP) ②



Sample Semivariogram for Residual ln(AAP) (3)



Sample Semivariogram for Residual ln(AAP) (4)



The behavior of γ for residual ln(AAP) is very confusing at first glance. The semi-variogram is definitely not stationary whereas γ for the raw variable (ln(AAP)) is stationary. This is exactly opposite what one normally expects; one usually subtracts the trend from the raw variable in order to construct a residual variable that is stationary.

Grid of estimated AAP based on elevation
⇒ rain_map.zgrd.

Grid of residual precip.

rain_diff.zgrd.

Gordon Wittmeyer

December 20, 1994

It is readily apparent from plot 4 on page 8 that the residual variogram is not stationary. Recall that the residual is given by

$$Res = \underset{(mm)}{AAP} - \exp(4.3146 + .0005872\,E)$$

where AAP is the measured average annual precipitation at the 42 stations, and E is the elevation in meters. This residual reflects AAP minus the orographic effect. However, the lack of stationarity of the RES is probably due to yet another effect, namely the rainshadow effect of the Sierra Nevada.

I developed a simple program to fit a polynomial trend surface to the RES.

The first order trend surface is given by

$$\widehat{RES}(mm) = 67.36 + 3.34\,X - 6.26 \times 10^{-5}\,y$$

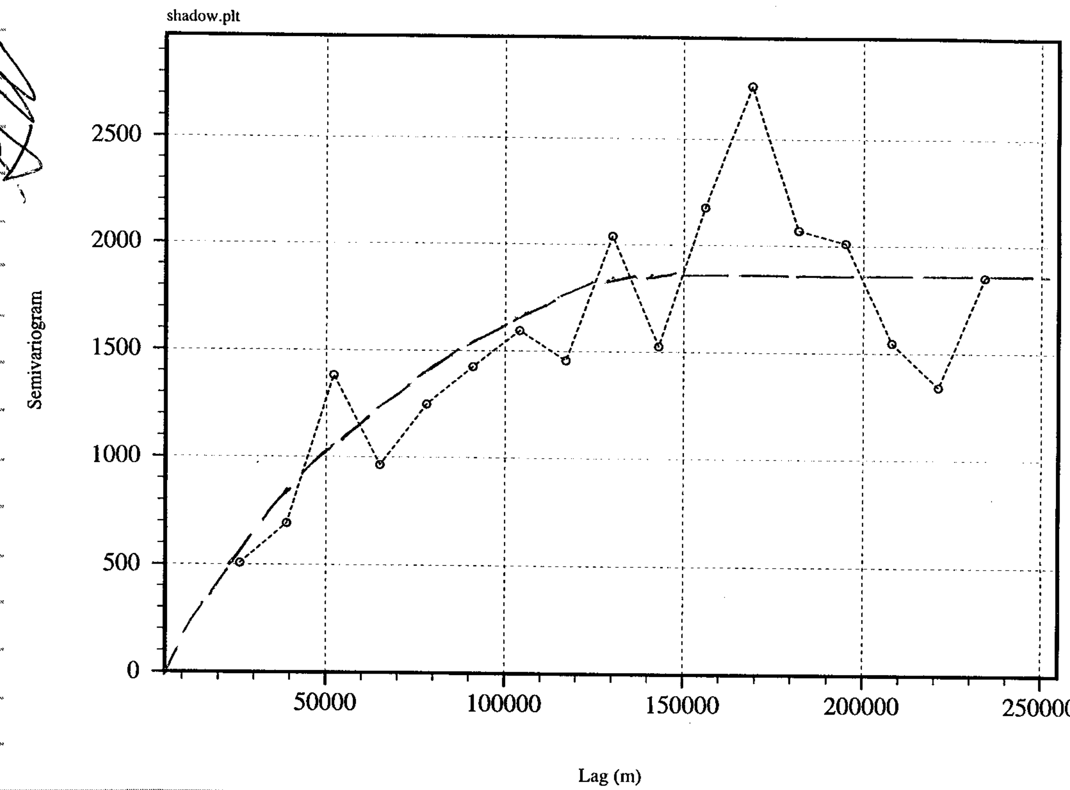
DW 12/12/94: $3.34 \times 10^{-4}\,X$

where x and y are the UTM coordinates in meters. The new rainshadow residual is given by

$$SHADRES = \underset{(measured)}{RES} - \underbrace{67.36 - 3.34 \times 10^{-4}\,x + 6.26 \times 10^{-5}\,y}_{=\widehat{RES}}$$

The semivariogram for SHADRES is given in plot 1 following. SHADRES with a 1st degree trend surface appears to be stationary and may be represented a spherical semi-variogram

Semivariogram for AAP Residuals without Rain Shadow Effect

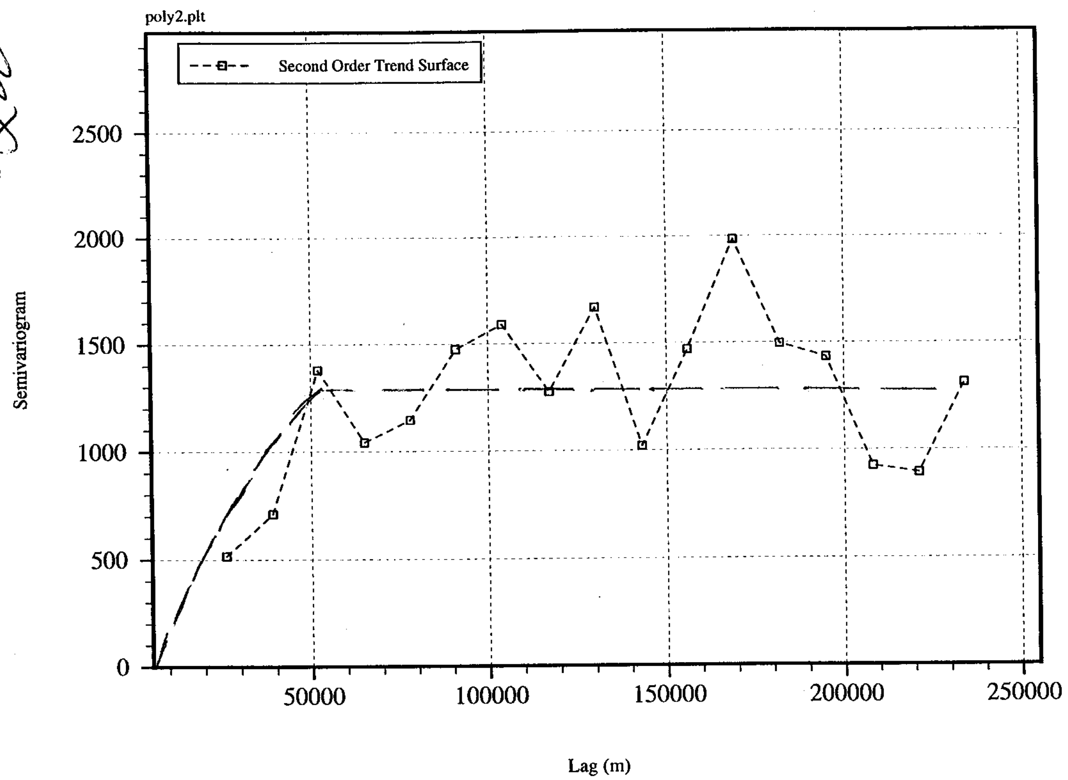


$$\gamma(h) = \begin{cases} \sigma^2\left(1.5\,\frac{h}{a} - .5\left(\frac{h}{a}\right)^3\right); & h < a \\ \sigma^2(1) & ;\ \text{otherwise} \end{cases}$$

where $a = 150000$ meters, $\sigma^2 = \text{sill} = 1830$

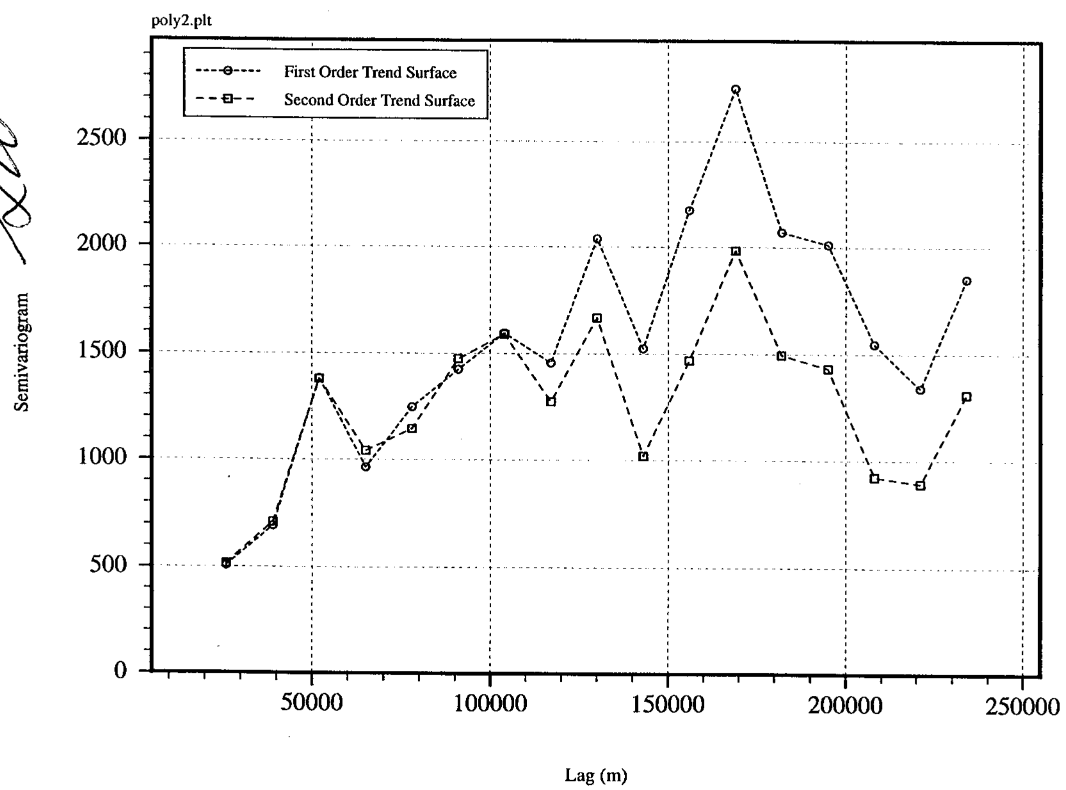
(2)

Semivariogram for AAP Residuals without Rain Shadow Effect



(3)

Semivariogram for AAP Residuals without Rain Shadow Effect



The second order trend surface is given by

$$\hat{RES}(mm) = 14942.43 - 1.16\times10^{-2}X - 5.52\times10^{-3}Y + 2.17\times10^{-10}X^2 + 2.81\times10^{-9}XY + 4.55\times10^{-10}Y^2$$

Show SHADRES = RES $-\hat{RES}$

The semivariogram for SHADRES is shown in plot 2 on page 12 for the case where a 2nd order trend surface was fitted to RES. The range is clearly less than that for $\gamma(h)$ for the 1st order trend surface. A suitable semivariogram model may be given by:

$$\gamma(h) = \begin{cases} 1300\left(1.5\left(\frac{h}{50000}\right) - .5\left(\frac{h}{5000}\right)^3\right) & ; h<50000 \\ 1300 & ; \text{otherwise} \end{cases}$$

Gordon Wittmeyer

12/21/94

I believe that the spatial distribution of AAP in southern Nevada can be geostatistically estimated using a combination of kriging with an external drift and nonstationary or universal kriging.

In the southern Nevada area rainfall varies spatially as a result of 3 primary factors:

1. Orographic effects,

2. Rainshadow effect of the Sierra Nevada,

3. Winter frontal precip in the ~~[illegible]~~ western (12/21/94) portion predominates, summer monsoonal precip is more important in the eastern portion.

Because the orographic effect can be modelled by a simple linear relationship between AAP and elevation, and because elevation measurements (or estimates) are dense in DEM coverages, it makes sense to treat it as the external drift model. Once the orographic effect is removed from the AAP data the rainshadow effect is more obvious, showing a pronounced northwest–southeast trend. If the proper polynomial trend surface is fitted to the residual AAP data, the resulting (AAP − Orographic Effect) − Rainshadow Effect = RESRAIN resembles a stationary RF which may be spatially estimated using kriging.

AAP^* : measured average annual precipitation in mm.

1. Orographic model

$$\hat{AAP} = \exp(a + b\,ELEV)$$

where ELEV is elevation in meters.

2. Orographic Residual

$$RESAAP = AAP^* - \hat{AAP}(ELEV^*)$$

$ELEV^*$ = elevation of measurement locations.

3. Orographic Residual model (polynomial trend surface) (aka rainshadow effect model)

$$\hat{RESAAP}_1 = \alpha + \beta X + \delta Y \quad ; \text{1st order model.}$$

X : x-coordinate in UTM (m)
Y : y-coordinate in UTM (m)

$$\hat{RESAAP}_2 = \alpha + \beta X + \delta Y + \mu X^2 + \nu XY + \sigma Y^2$$

; 2nd order model.

4. Rainshadow residual

$$RESRAIN = RESAAP - \hat{RESAAP}_i \quad ; i = 1 \text{ or } 2$$

(aka SHADRES on pages 10–13)

RESRAIN is intrinsic and may be spatially estimated by ordinary kriging.

The final spatial estimate of AAP is obtained by:

1. Kriging RESRAIN on the domain of interest

$\hat{RESRAIN}_j$; $j = 1, \ldots, \#$ nodes on grid

2. Estimating RESAAP on the same grid

$$\hat{RESAAP}_{1j} = \alpha + \beta X_j + \delta Y_j$$

or

$$\hat{RESAAP}_{2j} = \alpha + \beta X_j + \delta Y_j + \mu X_j^2 + \gamma X_j Y_j + \sigma Y_j^2$$

3. Estimating AAP due to orographic effect

$$\hat{AAP}_j = \exp(a + b\,ELEV_j)$$

4. Add up the effects

$$\hat{AAP}_j = \hat{AAP}_j + \hat{RESAPP}_j + \hat{RESRAIN}_j$$

Example of how we will do this.

1. Estimates of RESAAP at each node of the decimated DEM (36° → 38° N, -115 → -118° W) are in the file ...

/home/gwitt/Ischyetal/rain_.utm

X-UTM (m)	Y-UTM (m)	AAP (mm)	Elev (m)
571477.625	4059803.250	157.000	1036.320
587903.562	4052634.000	157.000	1005.230
589385.688	4056310.250	159.000	1149.096
563978.688	4070837.500	119.000	1043.026
580272.875	4074747.000	208.000	1219.200
592156.125	4072981.000	128.000	938.784
566792.750	4087499.500	225.000	1725.168
574151.625	4091332.750	226.000	1420.368
584585.750	4089544.250	177.000	1194.816
563756.062	4100456.000	202.000	1469.136
572648.250	4100527.750	245.000	1517.904
584456.188	4102523.750	177.000	1241.146
569503.250	4115256.750	295.000	2282.952
585797.938	4119179.500	193.000	1391.412
562189.625	4107877.500	229.000	1572.768
624217.062	4219539.000	321.000	1905.000
662317.312	4136958.250	128.000	1048.512
716377.625	3984526.000	139.000	769.620
719152.750	4166016.500	231.000	1343.254
613593.000	4030745.500	230.000	1828.800
660934.938	4055467.500	320.000	2301.240
665043.250	3994509.000	104.000	658.978
672351.250	4007634.000	106.000	554.736
731299.312	4044195.500	91.000	371.856
724110.562	4201242.500	313.000	1865.376
632002.438	3999496.000	270.000	1981.200
627448.062	4003200.750	354.000	1859.280
689009.125	3926628.750	185.000	1078.992
388755.781	4206366.500	142.000	1935.480
522268.719	4085491.250	159.000	1082.040
511918.781	4033668.500	69.000	-51.206
646379.062	4033013.500	106.000	890.016
410244.312	4163603.250	125.000	1516.380
479459.625	4172350.750	136.000	1734.312
619255.625	4049239.750	116.000	955.853
553630.938	4056012.250	85.000	663.245
403923.594	4248677.000	115.000	1387.145
589883.625	4008279.750	126.000	822.960
572688.438	4255867.000	121.000	1802.282
500000.000	4126063.250	90.000	1225.296
492719.281	4213046.500	163.000	1654.150
479561.312	4213068.500	126.000	1857.146

Measured AAP at 42 stations in Southern Nevada

/home/gwitt/Isohyetal/drift.f

```
*********************************************************
*** Program reads in the rainfall data and uses an   ***
*** external regression or drift model to produce    ***
*** the residuals, which are then used to compute    ***
*** the semivariogram. Gordon Wittmeyer, CNWRA       ***
*** 12/9/94.                                         ***
*********************************************************
c
      program drift
c
      implicit none
c
      real*4 long , lat , aap , elev , a1 , a2 , resaap
      real*4 reslog
c
      open(7,file='rain_.utm',status='old')
      open(8,file='rain_res.dat',status='unknown')
      open(9,file='rain_log.dat',status='unknown')
c
      a1 = 4.3146
      a2 = .0005872
c
    1 read(7,*,end=2) long , lat , aap , elev
      reslog = alog(aap) - (a1 + a2 * elev)
      resaap = aap - exp(a1 + a2 * elev)
      write(8,*) long , lat , resaap
      write(9,*) long , lat , alog(aap)
      goto 1
    2 stop
      end
```

/home/gwitt/Isohyetal/rain-res.dat

X-UTM (m)	Y-UTM (m)	RESAAP (mm)
571478.	4.05980E+06	19.5683
587904.	4.05263E+06	22.0545
589386.	4.05631E+06	12.1591
563979.	4.07084E+06	-18.9740
580273.	4.07475E+06	54.9883
592156.	4.07298E+06	-1.78169
566793.	4.08750E+06	19.0531
574152.	4.09133E+06	53.8028
584586.	4.08954E+06	26.1636
563756.	4.10046E+06	24.8004
572648.	4.10053E+06	62.6527
584456.	4.10252E+06	22.0038
569503.	4.11526E+06	9.24081
585798.	4.11918E+06	23.7060
562190.	4.10788E+06	40.6825
624217.	4.21954E+06	92.1158
662317.	4.13696E+06	-10.41914
716378.	3.98453E+06	21.4903
719153.	4.16602E+06	66.4263
613593.	4.03075E+06	11.1314
660935.	4.05547E+06	31.1557
665043.	3.99451E+06	-6.11794
672351.	4.00763E+06	2.42036
731299.	4.04420E+06	-2.03295
724111.	4.20124E+06	89.3799
632002.	3.99950E+06	30.6419
627448.	4.00320E+06	131.179
689009.	3.92663E+06	44.0812
388756.	4.20637E+06	-91.0175
522269.	4.08549E+06	17.8287
511919.	4.03367E+06	-3.56855
646379.	4.03301E+06	-20.1179
410244.	4.16360E+06	-57.1842
479460.	4.17235E+06	-71.0557
619256.	4.04924E+06	-15.0891
553631.	4.05601E+06	-25.3942
403924.	4.24868E+06	-53.8704
589884.	4.00828E+06	4.75152
572688.	4.25587E+06	-94.4869
500000.	4.12606E+06	-63.5604
492719.	4.21305E+06	-34.5352
479561.	4.21307E+06	-96.5421

← Measured AAP at 42 Stations in southern Nevada minus the orographic effect given by the model

RESAPP = APP − exp(4.3146 + .0005872 ELEV)

GW

Gordon Wittmeyer

12/22/94

Because the raw data on AAP contain an estimate of variance, and because the variance is not the same at all sample locations it is apparent that generalized least squares procedures are needed to determine the coefficients a & b of

$$\log(AAP) = (a + b\,ELEV).$$

I used the Numerical Recipes subroutine FIT to estimate a & b. The coefficients or the equation is

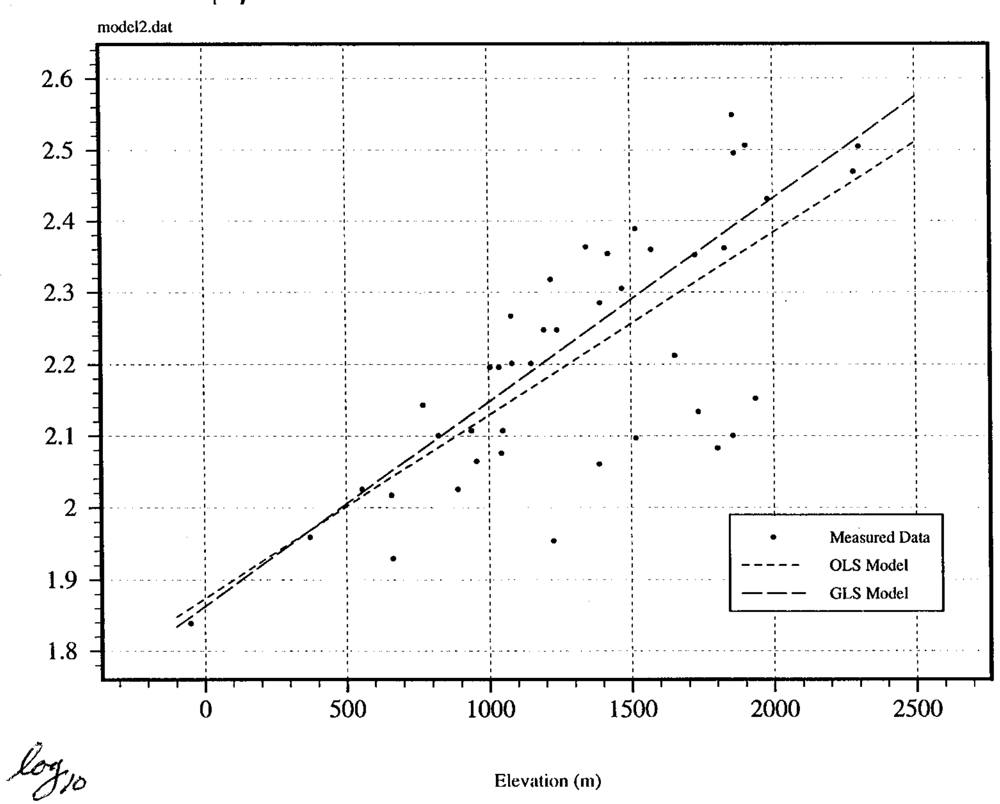
$$AAP = \exp(4.2893 + .00065548\,ELEV) \quad \text{Model 2 GLS}$$

compared to

$$AAP = \exp(4.3145 + .0005873\,ELEV) \quad \text{Model 1 OLS}$$

obtained using OLS!

GW



★ $\log_{10}$

EPS version of the above file is given:

/home/gwitt/Isohyetal/orograph.eps

2 Separate files of RESAAP = AAP − exp(a + b ELEV)

For OLS model: /home/gwitt/Isohyetal/rain-res_ols.dat

For GLS model: /home/gwitt/Isohyetal/rain-res_gls.dat

Polynomial drift models:

A. For OLS model based residuals

i.) 1st order drift

$\widehat{RESAPP} = 67.6095 + 3.337 \times 10^{-4} X - 6.262 \times 10^{-5} Y$

RESRAIN = RESAPP − $\widehat{RESAPP}$ in in

"loc"
/home/gwitt/Isohyetal/ols-poly1.dat

Model coefficients are in → "loc"/ols_poly1.coef

Variogram → "loc"/ols_poly1.plt

ii) 2nd order drift

RESRAIN : "loc"/ols_poly2.dat
Coefficients : "loc"/ols_poly2.coef
Variogram : "loc"/ols_poly2.plt

iii) 3rd order drift

RESRAIN : "loc"/ols_poly3.dat
Coefficients : "loc"/ols_poly3.coef
Variogram : "loc"/ols_poly3.plt

B For GLS model based residuals

i) 1st order drift model

RESRAIN : "loc"/gls_poly1.dat
Coeffs : "loc"/gls_poly1.coef
Variogram : "loc"/gls_poly1.plt

ii) 2nd order drift model

RESRAIN : "loc"/gls_poly2.dat
Coeffs : "loc"/gls_poly2.coef
Variogram : "loc"/gls_poly2.plt

iii) 3rd order drift

RESRAIN : "loc"/gls_poly3.dat
Coeffs : "loc"/gls_poly3.coef.
Variogram : "loc"/gls_poly2.plt.

Example of building the AAP distribution using an ~~extrinsic~~ external drift model and residual kriging. GW 12/22/94

1. Krige RESRAIN based on GLS and the 3rd order trend.

   a.) Kriging location in small_coord.utm

   b) Scattered data in gls-poly3.dat

   c) Assume spherical variogram model with
      range = 80,000 (m)
      sill = 1000

   d) Kriging output: gls_poly3.krig

2 Next:

   a) Estimate $\widehat{RESAPP}$ using the 3rd order drift model based on GLS.

   b) Estimate $\widehat{AAP}$ by the GLS model and add

$$\widehat{RESRAIN} + \widehat{RESAPP} + \widehat{AAP} = \hat{\hat{AAP}}$$

Gordon Wittmeyer

12/27/94

The program "builder.f" was written to add together the kriged rainshadow residuals, the mean rainshadow effect, and the orographic effect.

Files: (all in "/home/gwitt/Isohyetal")

1. Kriged rainshadow residuals: "gls_poly3.krig"
2. Elevation data file: "~~small_coord.utm~~" "small.utm" GW 12/28/94
3. File containing coefficients of polynomial trend surface describing the mean rainshadow effect "gls_poly3.coef".
4. Output file containing the average annual precipitation estimated for Southern Nevada using:

   i. GLS to fit the orographic model,

   ii. A 3rd degree polynomial trend surface to model the mean rainshadow effect,

   iii. Rainshadow residuals kriged with a spherical variogram model r = 80,000 m, sill = 1000,

   is "gls_poly3.aap."
5. Output file containing the orographic and mean rainshadow effect only in "gls_poly3.mean"

Use EarthVision to grid and contour both the aap and mean aap estimates.

1. On SGI Onyx ~~gls-poly3.aap~~ gls-poly3.mean is called GW 12/27/94

   gls-poly3_mean.dat ⟹

   gls-poly3_mean.zgrd

2. On SGI Onyx gls_poly3.~~p~~aap GW is

   gls-poly3_aap.dat →

   gls-poly3_aap.zgrd

Gordon Wittmeyer

1/3/95

I discovered a mistake in fitting the precip elevation model using GLS. Apparently I had typed in the length of record instead of the standard deviation and thus the GLS estimates are incorrect.

rain-std.utm in /home/gwitt/Isohyetal

UTM Coords X	Y	~~Elv~~ AAP (mm) AU 1/3/95	Elev (m)	# years of record	σ
571477.625	4059803.250	157.000	1036.320	8	23
587903.562	4052634.000	157.000	1005.230	15	17
589385.688	4056310.250	159.000	1149.096	13	18
563978.688	4070837.500	119.000	1043.026	16	15
580272.875	4074747.000	208.000	1219.200	21	21
592156.125	4072981.000	128.000	938.784	19	12
566792.750	4087499.500	225.000	1725.168	12	25
574151.625	4091332.750	226.000	1420.368	13	23
584585.750	4089544.250	177.000	1194.816	25	17
563756.062	4100456.000	202.000	1469.136	18	18
572648.250	4100527.750	245.000	1517.904	20	23
584456.188	4102523.750	177.000	1241.146	22	17
569503.250	4115256.750	295.000	2282.952	17	31
585797.938	4119179.500	193.000	1391.412	8	22
562189.625	4107877.500	229.000	1572.768	8	36
624217.062	4219539.000	321.000	1905.000	47	16
662317.312	4136958.250	128.000	1048.512	26	10
716377.625	3984526.000	139.000	769.620	50	9
719152.750	4166016.500	231.000	1343.254	51	11
613593.000	4030745.500	230.000	1828.800	8	33
660934.938	4055467.500	320.000	2301.240	9	27
665043.250	3994509.000	104.000	658.978	33	8
672351.250	4007634.000	106.000	554.736	32	8
731299.312	4044195.500	91.000	371.856	26	13
724110.562	4201242.500	313.000	1865.376	44	16
632002.438	3999496.000	270.000	1981.200	8	36
627448.062	4003200.750	354.000	1859.280	8	47
689009.125	3926628.750	185.000	1078.992	50	14
388755.781	4206366.500	142.000	1935.480	15	17
522268.719	4085491.250	159.000	1082.040	47	12
511918.781	4033668.500	69.000	-51.206	18	7
646379.062	4033013.500	106.000	890.016	42	8
410244.312	4163603.250	125.000	1516.380	31	9
479459.625	4172350.750	136.000	1734.312	39	12
619255.625	4049239.750	116.000	955.853	25	16
553630.938	4056012.250	85.000	663.245	21	11
403923.594	4248677.000	115.000	1387.145	53	7
589883.625	4008279.750	126.000	822.960	20	16
572688.438	4255867.000	121.000	1802.282	20	13
500000.000	4126063.250	90.000	1225.296	14	13
492719.281	4213046.500	163.000	1654.150	29	10
479561.312	4213068.500	126.000	1857.146	22	11

Program chi_fit.f must be modified and rerun.

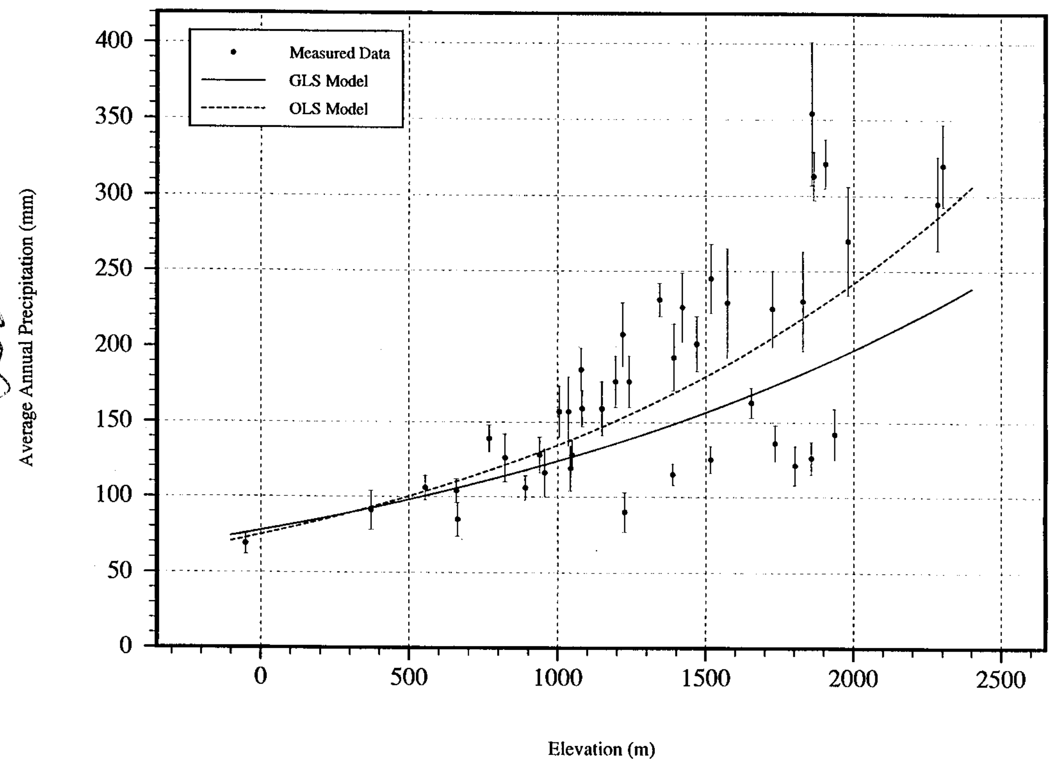
GW 1/3/95

Correct ~~GSD~~ GLS model

AAP = exp(4.35098 + .000468369 ELEV)

Compare to OLS model

AAP = exp(4.3145 + .0005873 ELEV)



This file in /home/gwitt/Isohyetal/orograph.eps

Now I must redo the steps outlined on pages 20-24 for the GLS orographic model.

1. Construct rain_res_gls.dat using drift.f.

2. Fit new polynomial drift models to orographic residuals using rainshad.f

i) 1st order drift model

RESRAIN : "loc"/gls_poly1.dat
Coef : "loc"/gls_poly1.coef
Variogram : "loc"/gls_poly1.plt

ii) 2nd order drift model

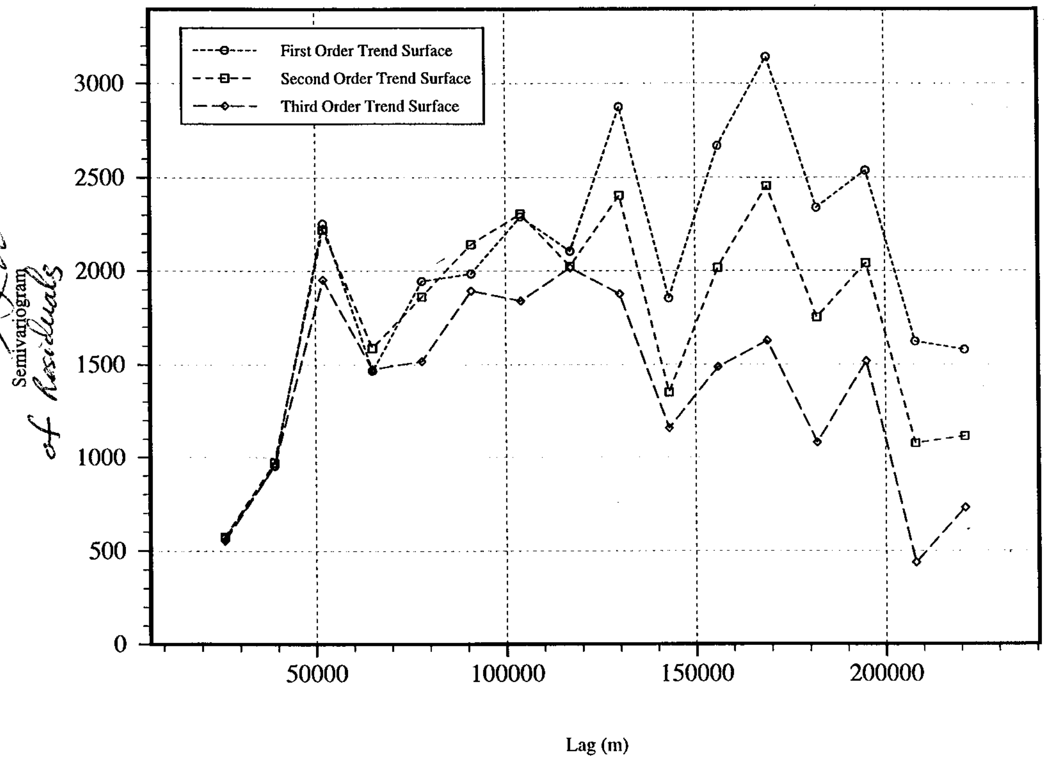
RESRAIN: "loc"/gls_poly2.dat
Coef : "loc"/gls_poly2.coef
Variogram : "loc"/gls_poly~~3~~2.plt

GW 1/3/95

iii) 3rd order drift model

RESRAIN: "loc"/gls_poly3.dat
Coef : "loc"/gls_poly3.coef
Variogram : "loc"/gls_poly3.plt

For GLS Orographic Model



GW 1/9/95

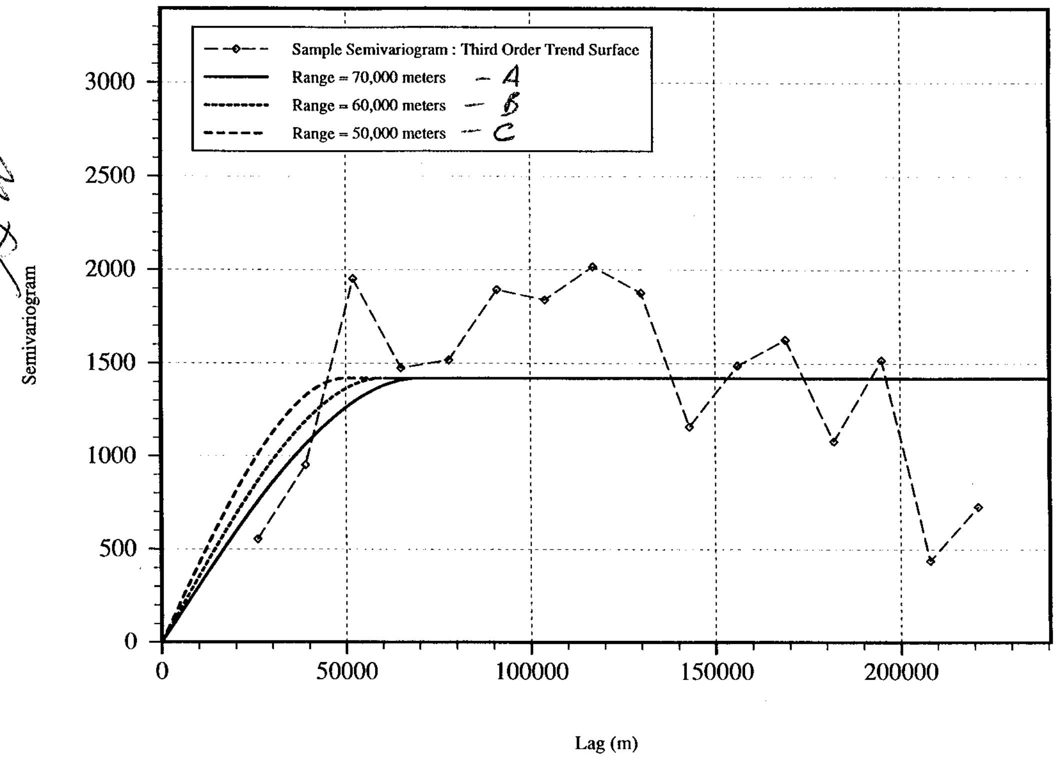
This plot is saved as /home/gwitt/Isohyetal/ ~~variogram.eps~~ gls_vario.eps GW

Eye-fitting model semivariogram to the ~~above~~ sample semivariogram

For the semivariogram corresponding to the 3rd order trend surface

A: Model 1 : Spherical sill = σ^2 = 1420, range = 70,000
B: Model 2 : " " " , range = 60,000
C: Model 3 : " " " , range = 50,000

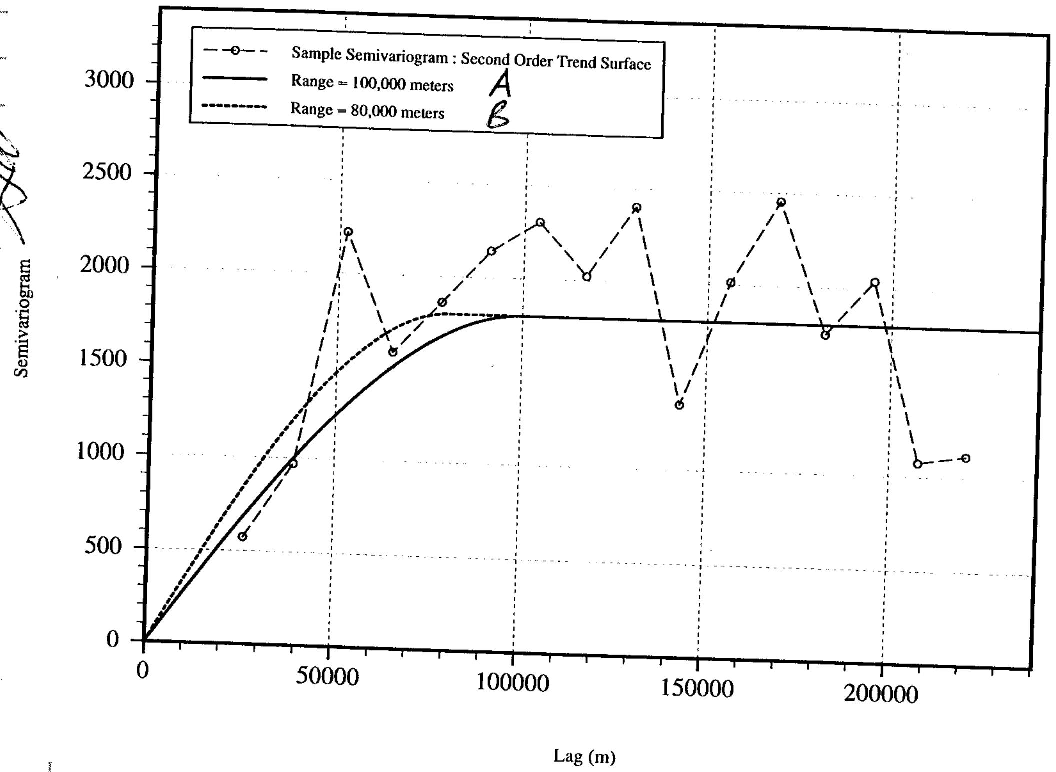
Sample Semivariogram & Model γ's for residuals after 3rd trend surface was fitted to AAP-orographic effect



For semivariogram corresponding to the 2nd order trend surface

Model A : Spherical sill = σ^2 = 1800, range = 100,000

Model B : " " " " , range = 80,000



I feel that for the precip-elevation model fitted using GLS, the resulting residuals are best modelled using a 2nd order trend surface. This argument is based on the observation that the residuals RESRAIN produce a fairly stationary sample semivariogram. The selected semivariogram model is a spherical with sill ≅ 1800 & range = 80,000 m.

Now produce maps of the final $\hat{AAP}$ values

1. Kriged rainshadow residuals are in gls-polyz.krig

2. elevation data is in small.utm

3. drift coefficients gls-polyz.coef

4. $\hat{AAP}$ is in gls-polyz.aap.

5. $\hat{RESAAP}$ + $\hat{AAP}$ is in gls-polyz-oro.shad.

6. $\hat{AAP}$ is in gls-polyz.oro

Transfer files to ONYX and visualize.

1. gls-polyz.aap → gls-polyz-aap.dat

2. gls-polyz-oro.shad → gls-polyz-oro-shad.dat

3. gls-polyz.oro → gls-polyz-oro.dat

Gordon Wittmeyer

1/4/95

On the ONYX the following EarthVision grid files were created

① gls-poly2-aap.dat ⋆ .2grd } $\hat{AAP} = \hat{RESRAIN} + \hat{RESAAP} + \hat{AAP}$

② gls-poly2-oro-shad.dat ⋆ .2grd } $\hat{RESAAP} + \hat{AAP}$

③ gls-poly2-oro.dat ⋆ .2grd } $\hat{AAP}$

These files reflect the new GLS estimate of the precip-elevation relation and the 2nd order trend surface fitted to ~~rain shadow~~ AW 1/4/95 orographic residuals

Need to briefly test a few more semivariogram models for the residuals obtained after removing the orographic effect with elev-precip model, and the residual rain shadow effect using a 2nd order trend surface

Model A: Spherical sill = 1800, range = 100,000

"loc" RMSE = 1.2682 } from cross-validation
SMSE = 3.6602
/home/zwitt/Isohyetal/gls-poly2-cross.mod1

Model B: Spherical sill = 1800, range = 80,000

RMSE = 1.1533
SMSE = 2.8781

/loc/gls-poly2-cross.mod2

Model C: Spherical sill = 1800, range = 60,000

RMSE = 1.0188
SMSE = 2.0726
/loc/gls-poly2-cross.mod3

Model D: Spherical sill = 1800, range = 40,000

RMSE = .86288
SMSE = 1.3632
/loc/gls-poly2-cross.mod4

I would select this model!!

Model E: Spherical sill = 1800, range = 20,000

RMSE = .88250
SMSE = 1.0227
/loc/gls-poly2-cross.mod5

Model F: Nugget = 400, Spherical sill = 1400, range = 40,000

RMSE = 1.1096
SMSE = 1.5375
/loc/gls-poly2-cross.mod6

Model G: Spherical: sill = 2000, range = 40,000

RMSE = .7766
SMSE = 1.2269
/loc/gls-poly2-cross.mod7

Model H: Spherical: sill = 2000, range = 40,000
neighborhood r = 30,000, num = 4/quad

Option not functioning for cross-validation.

Model D is selected as the best model among three tested by cross-validation

$$RMSE = \frac{1}{\sum n_i} \sum_{k=1}^{n_i} \left[Z_i^*(x_k) - z_i(x_k) \right]^2$$

is a measure of accuracy, would like

$RMSE = 0$

$$SMSE = \frac{1}{n_i} \sum_{k=1}^{n_i} \frac{\left[Z_i^*(x_k) - z_i(x_k) \right]^2}{\sigma_k^2(x_k)}$$

is a measure of consistency of the estimation variance

$$1 - 2(2/n_i)^{.5} \le SMSE \le 1 + 2(2/n_i)^{.5}$$

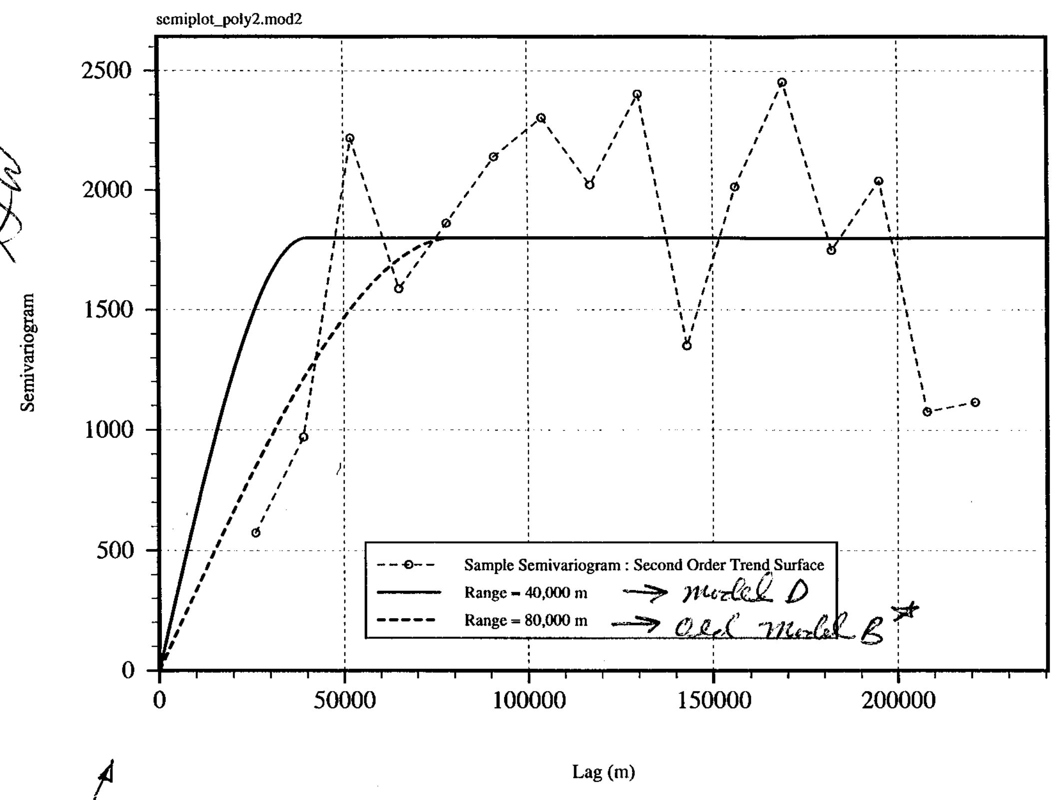
$n_i = 41$

$$.5583 \le SMSE \le 1.442$$

Although Model G appears to be better than D based on RMSE & SMSE I prefer to use a model with a sill equal to the sample variance.

Re-krige RESRAIN using model D

⇒ gls_poly2.krig2 on "loc"



* See page 29 for defn of "old" Model B.

EPS file in /"loc"/ modeld_semi.eps

Now produce maps of final $\hat{AAP}$ values

1. Kriged rainshadow residuals are in gls_poly2.krig2
2. Elevation data is in small.utm
3. drift coefficients are in gls_poly2.coef
4. $\hat{AAP}$ is in gls_poly2.aap2
5. $\hat{RESAPP}$ + $\hat{AAP}$ is in gls_poly2_oro.shad2
6. $\hat{AAP}$ in gls_poly2.oro2

On the ONYX

① gls-poly2_aap2.dat ⋆ / .zgrd } $\hat{AAP}$

② gls-poly2-oro-shad2.dat ⋆ / .zgrd } $\hat{RESAAP} + \hat{AAP}$

③ gls-poly2_oro2.dat ⋆ / .zgrd } $\hat{AAP}$

Gordon Wittmeyer

1/9/95

Need to redo all isohyetals and recharge maps based on the OLS orographic precip. model so that the new cross-validation procedure can be used to select the model semivariogram for RESRAIN.

Recall:

1. Orographic model using OLS is

$$\hat{AAP} = \exp(4.3145 + .0005873\ ELEV)$$

2. Fit polynomial trend surface to

$$\overset{\star}{RESAAP} = \overset{\star}{AAP} - \hat{AAP}$$
$$= (\text{measured AAP} - \text{predicted AAP})$$

3. Remove polynomial trend surface from $\overset{\star}{RESAPP}$

$$\overset{\star}{RESRAIN} = \overset{\star}{RESAPP} - \hat{RESAPP}$$
$$= \left(\overset{\star}{AAP} - \hat{AAP} - \sum_{i=1}^{np} a_i f_i(\underline{X})\right)$$

4. Fit model semivariogram to $\overset{\star}{RESRAIN}$ using cross-validation.

5. Krige estimates of $\hat{RESRAIN}$ at all grid points

6. Add up all effects.

$$\hat{AAP} = \hat{RESRAIN} + \hat{RESAAP} + \hat{AAP}$$

i) RESAAP* is in /loc/ rain_res-ols.dat
obtained using drift.f

ii) Fit polynomial surface to RESAAP* using
rainshod.f

a) 1st order drift model

RESRAIN : "loc" / ols_poly1.dat
Coef : " / ols_poly1.coef
γ : " / ols_poly1.plt

b) 2nd order drift model

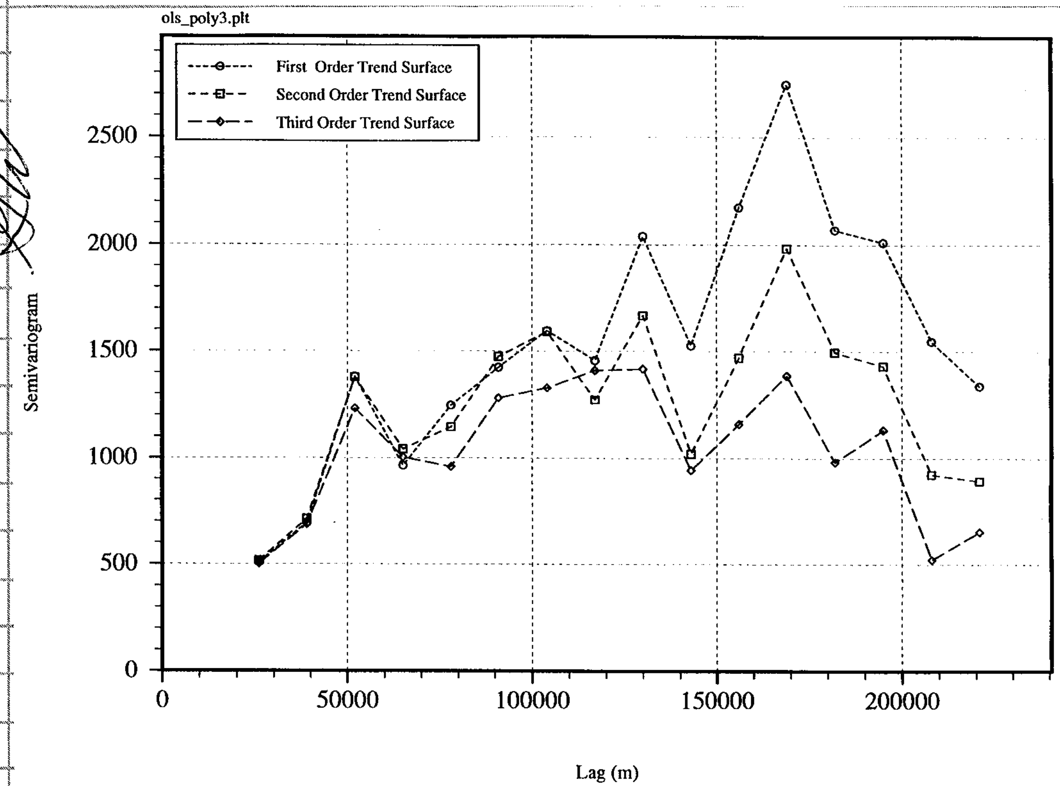
RESRAIN : loc / ols_poly2.dat
Coef : " / ols_poly2.coef
γ : " / ols_poly2.plt

c) 3rd order drift model

RESRAIN : loc / ols_poly3.dat
Coef : " / ols_poly3.coef
γ : " / ols_poly3.plt

iii) Plot semivariograms (sample semivariogram)

Plot file is ols_vario.eps



It appears that a 3rd order trend needs to be removed from RESAAP before RESRAIN yields a stationary sample semivariogram.

(iv) Use cross validation to select final semivariogram model

a) Model 1 Spherical sill = 1080, range = 60,000 m

RMSE = 1.3290
SMSE = 3.2540

b) Model 2 Spherical sill = 1080, range = 40,000

RMSE = 1.1565
SMSE = 2.0873

c) Model 3 Spherical sill = 1080, range = 20,000

RMSE = 1.0756
SMSE = 1.2953

d) Model 4 Spherical sill = 1080, range = 10,000

RMSE = 1.0561
SMSE = 1.0967

e) Model 5 Spherical sill = 1080, range = 15,000

RMSE = 1.0480
SMSE = 1.1571

f) Model 6 Pure nugget = 1080
test failed!

g) Model 7 Spherical sill = 1080 range = 17,500

RMSE = 1.0574
SMSE = 1.2172

h) Model 8 Spherical sill = 1080 range = 10

RMSE = 1.0448
SMSE = 1.0709

↑ Nearly ∅ correlation

i) Model 9 Spherical sill = 1080, range = .001
RMSE = 1.0448
SMSE = 1.0708

The results of this cross-validation study are, to put it mildly, somewhat confusing. Note that for models 8 & 9 both the RMSE & SMSE reach their smallest values, however, we know that the residuals must be correlated since they are derived from the polynomial drift model. Note that SMSE will approach one as the correlation length or range goes to zero and ~~the~~ when all samples are used to krige. This is because the kriged estimate at every point is identically equal to the mean of the sample values! So SMSE is really not the best measure.

I think that eye-fitting the semivariogram may make more sense until problems with cross-validation can be resolved.

Gordon Wittmeyer

1/12/95

I. Check contours of polynomial drift function

Based on visual inspection it appears that the 3rd order trend surface polynomial that I fit to rain-res-ols.dat is very similar to that fitted by EarthVision.

Compare: rain_res_ols.zgrd (3rd degree trend surface)

to ols_poly3_map.zgrd

(301 X 249 (396348.9, 3972563) → (693791.1, 4218688)

→ This portion of rain-res-ols.zgrd extracted via refgrd to make trend3.zgrd

The figures look very similar leading me to conclude that my polynomial fitting program works quite well.

II raw semivariogram for

$AAP^* - \hat{AAP} = RES\hat{AAP}$ for ols eqn.

rain_ols.eps

raw semivariogram for

$AAP^* - \hat{AAP} = RES\hat{AAP}$ for gls eqn.

rain_gls.eps

Gordon Wittmeyer

1/~~18~~ 16/95 GW

From earlier work I know that the variance of the rain shadow residuals after removing an nth order polynomial trend surface is ~~given~~ to:

1. For OLS model

a. 1st order poly. $\sigma^2 = 1560$
b. 2nd " " $\sigma^2 = 1310$
c. 3rd " " $\sigma^2 = 1080$ ✓

2. For GLS model

a. 1st order poly. $\sigma^2 = 2040$
b. 2nd " " $\sigma^2 = 1800$ ✓
c. 3rd " " $\sigma^2 = 1420$

Because selecting the model semivariogram using cross-validation statistics produced some very strange results I have built a simple non-linear least squares program to fit model γ's to sample γ's.

1. For OLS model / 3rd order poly.

sill = σ^2 = 1080
nugget = 0
range = 69,600 m.

2. For GLS model / 2nd order poly.

sill = σ^2 = 1800
nugget = 0 , GW 1/19/95
range = 76,~~9~~100 m

Gordon Wittmeyer

1/17/95

Need to rebuild the AAP & other maps using these new semivariogram models.

A. For the OLS model.

1. Perform Kriging range = 69,600 m, sill = 1080, nugget = φ (resid_krig.f)

a. Get cross-validation stats. (ols-poly3.cross)

RMSE = 1.4129

SMSE = 3.8560

b. Krige on the 3° x 2° area

i) Data : ols_poly3.dat DW 1/17/95

ii) Kriging locations : ~~ols~~ small-coord.utm

iii) Kriging output : ols_poly3.krig

2. Add orographic, rainshadow and kriged residual rainshadow effects. (builder.f)

i) Kriged rainshadow residuals : ols_poly3.krig

ii) elevation data : small.utm

iii) Coefficients of mean rain shadow polynomial : ols_poly3.coef

iv) AAP : ols_poly3.aap

v) Orographic + mean rain shadow : ols_poly3_oro.shad

vi) Orographic effect : ols_poly3.oro

vii) Mean rain shadow ols_poly3.shad

B. For the GLS model

1 Kriging range = 76,100 m, sill = 1800, nugget = φ

a) Cross-validation stats (gls_poly2.cross)

RMSE = 1.8947

SMSE = 4.5597

b) Krige on the 3° x 2° area

i) Data : gls_poly2.dat

ii) Kriging location : small-coord.utm

iii) Kriging output : gls_poly2.krig

C.)

2. Add orographic, rainshadow & Kriged residuals rain shadow effects:

i) Kriged rainshadow residuals : gls_poly2.krig

ii) elevation data : small.utm

iii) Coefficients of mean rain shadow polynomial : gls_poly2.coef

iv) AAP : gls_poly2.aap

v) Orographic + mean rain shadow : gls_poly2_oro.shad

vi) Orographic effect : gls_poly2.oro

vii) Mean rain shadow gls_poly2.shad

Using EarthVision of the SGI ONYX I have created the following grids.

OLS:

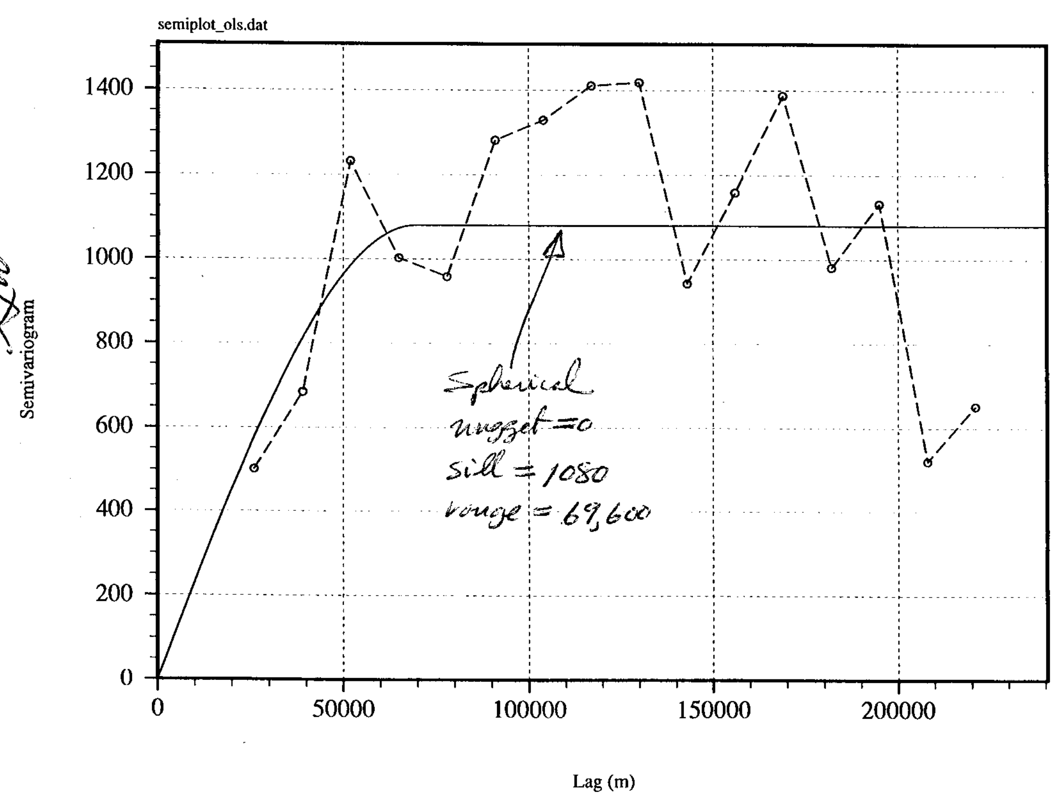
i) ols_poly3_aap.zgrd

ii) ols_poly3_oro.zgrd

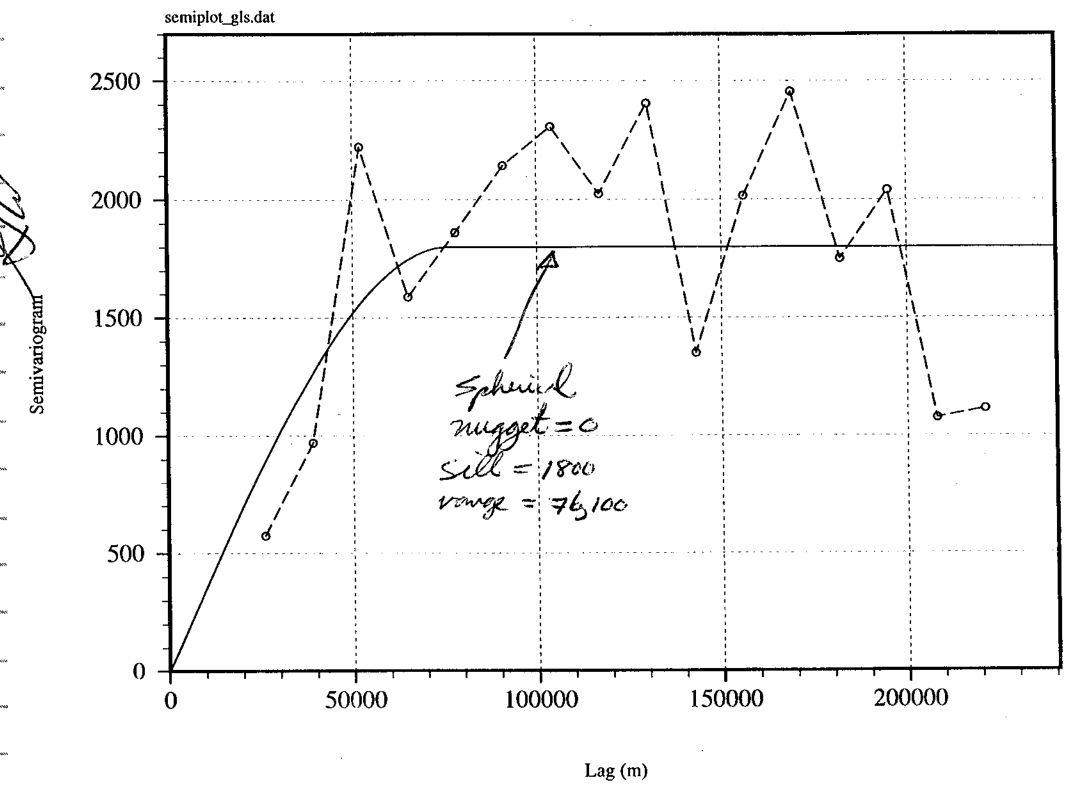
GLS:

i) gls_poly2_aap.zgrd

ii) gls_poly2_oro.zgrd



Semivariogram of rain shadow residuals from OLS oro model

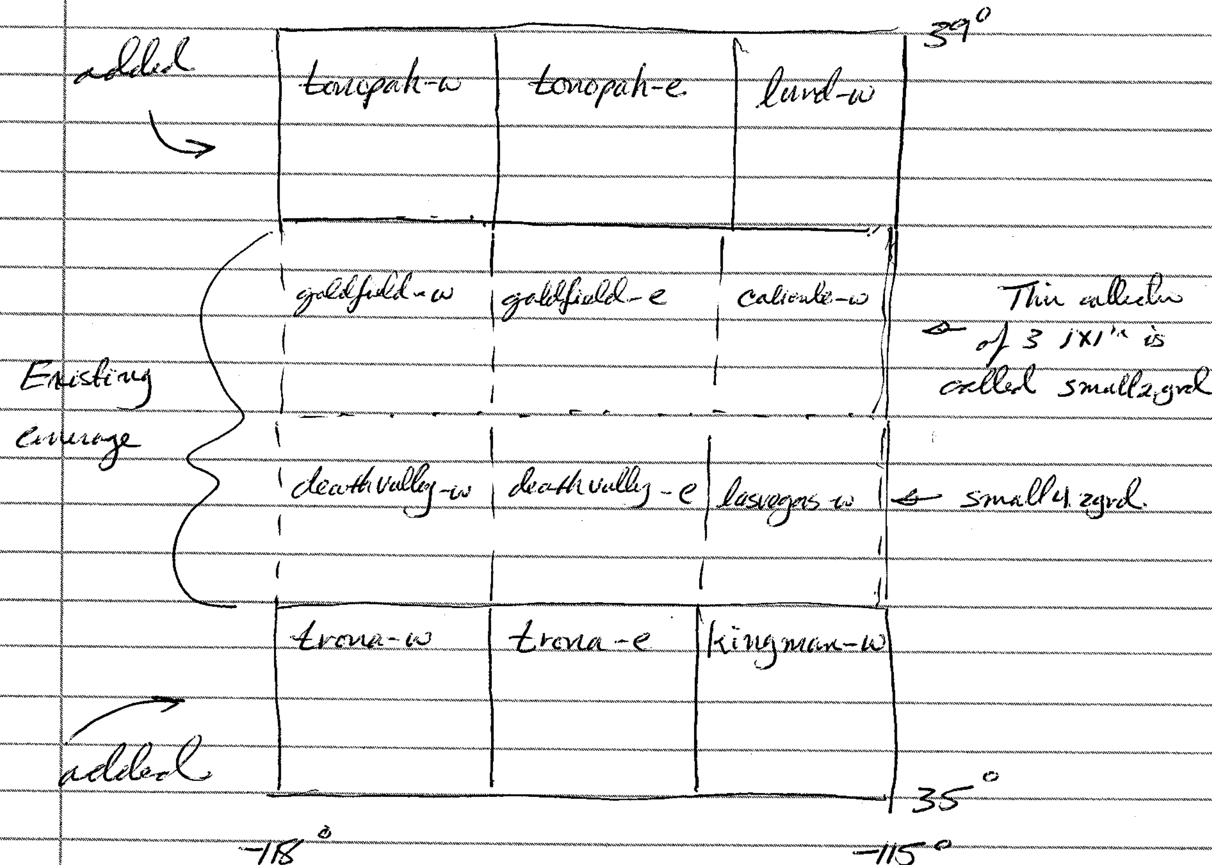


Semivariogram of rain shadow residuals from GLS oro model

Gordon Wittmeyer

April 2, 1995
(A Sunday!!)

Need to extend the region by adding the 1X1 degree dems from:



1. Read each of the six into EV and create a grid. w/pscrd

a kingman-w → king_w.zgrd.
b trona-e → trona_e.zgrd
c trona-w → trona_w.zgrd
d lund-w → lund_w.zgrd
e tonopah-e → tono_e.zgrd
f tonopah-w → tono_w.zgrd

2. Now reduce the grid density of each "dem".zgrd from 1201 x 1201 to 101 x 101

a. king_w_small.zgrd = refgrd (king_w.zgrd, 101, 101, -417600, -414000, 126000, 129600)

b trona_e_small.zgrd = refgrd (trona_e.zgrd, 101, 101, -421200, -417600, 126000, 129600)

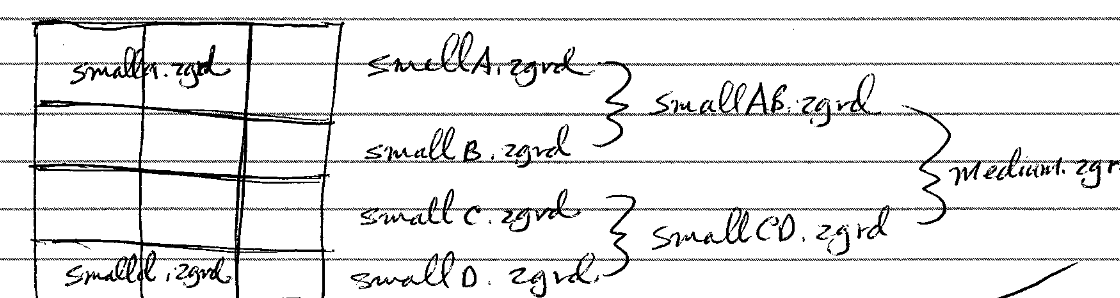
c trona_w_small.zgrd = refgrd (trona_w.zgrd, 101, 101, -424800, -421200, 126000, 129600)

d lund_w_small.zgrd = refgrd (lund_w.zgrd, 101, 101, -417600, -414000, 136800, 140400)

e tono_e_small.zgrd = refgrd (tono_e.zgrd, 101, 101, -421200, -417600, 136800, 140400)

f tono_w_small.zgrd = refgrd (tono_w.zgrd, 101, 101, -424800, -421200, 136800, 140400)

3. Combine all 12 1°x1° "small" grids into one grid using the function "union".



4. Convert medium.zgrd to an ascii file using the "ev-export" utility

% ev-export -o medium.dat medium.zgrd

5. Medium.dat is in arc-seconds, convert to decimal degrees using the program degrees.f
=> file in "medium.out"

6. Use Evenden's Cartographic projection procedure to convert the decimal degrees in "medium.out" to UTM coordinates

=> file in "medium.utm"

X (UTM m)   Y (UTM m)   Elevation (m)

120701 records in this file

All basic topographically based computations will be made using "medium.utm"

Now to begin the laborious process of building AAP maps.

I. First for OLS

i) krige on 3° X 4° area   resid_krig.x
  i) Data ols-poly3.dat
  ii) kriging location medium_coord.utm
  iii) kriging output m_ols-poly3.krig.ansa

ii) Now add all effects together : builder.f

  i) kriged rainshadow ~~rsd~~ rsw residuals : ~~ols~~ rsw m_ols-poly3.krig (1/2/95)
  ii) elevation data : medium.utm
  iii) Coefs of mean rainshadow polynomial : ols-poly3.coef
  iv) $\hat{AAP}$: m_ols-poly3.aap
  v) Orographic + mean rain shadow : m_ols-poly3_oro.shad
  vi) orographic effect : m-ols-poly3.oro
  vii) Mean rain shadow : m_ols-poly3.shad

Need to clip the $\hat{AAP}$ contours with a polygon forming the hull of the precip stations. There are serious errors caused by extrapolation with the trend surface.

Polygon formed by: Mina
Rattlesnake
Adaven
Pioche
Caliente
Overton
Boulder City
Searchlight
Roberts Ranch
Death Valley
Dyer
Baralt

"precip_station.ply"

Clipped files on Performer   m_aap_hull.zgrd
m-oro_hull.zgrd.

Gordon Wittmeyer

June 26, 1995

Development of a PORFLOW grid to model free-surface flow in a 2D vertical cross-section transecting the steep hydraulic gradient region near Yucca Ridge.

Using the program MeshMaker to construct the grid and assign the properties. Initial exported grid in "dmesh.exp" on performer. Development of a code to translate "dmesh.exp" into PORFLOW compatible ~~out~~ ASW input file.

Gordon Wittmeyer

This research project was formally closed on January 19, 1996. The work described in this scientific notebook is primarily related to the development of a procedure to estimate average annual precipitation and average annual recharge within the Death Valley region.

The spatial estimation procedure described herein combines universal kriging with kriging in the presence of an external drift function. The external drift function accounts for orographic effects, while universal or non-intrinsic kriging is used to handle the Sierra Nevada rain shadow effect.

Gordon Wittmeyer

Principal Investigator

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